GAS ENGINE IGNITION

ENGINEERING EDUCATION SERIES

GAS ENGINE IGNITION

PREPARED IN THE
EXTENSION DIVISION OF
THE UNIVERSITY OF WISCONSIN

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PREFACE

This volume has been developed to satisfy the demand for a systematic course of instruction dealing with the ignition systems used on stationary and automobile internal combustion engines. In preparing the text, the authors have had in mind the needs of the men in the factories and repair shops who have to install, adjust, and repair ignition systems. For this reason, a few systems have been included which are no longer manufactured, but which are to be found in operation in large numbers.

The division of the text matter into chapters has been made with the idea of making uniform assignments of work for home study, rather than of following any more logical classification.

The authors wish to express their appreciation of the hearty co-operation received from the manufacturers in supplying the cuts for the illustrations of the book.

E. B. N.

MADISON, WIS.,
April, 24, 1916.

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GAS ENGINE IGNITION

CHAPTER I

CLASSIFICATION; THE MAKE-AND-BREAK SYSTEM

1. Methods of Ignition.—In the development of the internal combustion engine, a number of methods of igniting the explosive charge within the cylinder have been tried. These can be grouped in the four following classes:

1. Ignition by an open flame.
2. Ignition by a hot tube or bulb.
3. Ignition by the heat of compression.
4. Ignition by an electric spark.

The first method named was tried only for a short period and did not prove satisfactory; hence, it may be given only passing notice here. It consisted of two gas jets or burners, one outside the combustion chamber and the other inside of a revolving cock or valve which was alternately connected to the outside flame and then to the combustion chamber. The jet outside the cylinder was kept burning all the time. The revolving cock surrounding the second jet was first turned to connect with this outside flame, thus lighting the gas at this second jet. The cock was then turned to communicate with the combustion chamber at the desired instant for ignition of the charge. The explosion which followed extinguished this flame and made necessary the outside flame for reigniting it after each explosion.

The other three methods of ignition have all survived and are used in different types of internal combustion engines. The method of electric ignition is the most common and is found in many diverse forms.

2. Hot-tube Ignition.—The hot tube as a means of ignition was the prevailing method for a number of years and is still used to some extent, especially in the natural gas regions, where gas is cheap. As shown in Fig. 1, this system consists of a small tube having the outer end closed and having the open inner end connected to the combustion chamber of the engine. Surrounding the tube is a chimney, usually of cast iron lined with asbestos. A gas or gasoline burner at the base of this chimney surrounds the tube with flame and keeps it at a red heat. The temperature of this tube on the inside is sufficient to ignite the explosive mixture within the cylinder when it comes into contact with the tube.

The control of the time of ignition is effected in the following manner: After a working stroke of the engine the tube is filled with burnt gases. During the exhaust stroke most of the burnt gases are exhausted from the cylinder, but the tube remains filled with the dead gases at atmospheric pressure. On the compression stroke of the piston these dead gases are compressed into the upper end of the tube and the fresh mixture follows it up into the tube, where it is ignited by the hot metal. This flame then shoots back into the main combustion chamber and fires the charge in the cylinder. If the flame which heats the tube is too close to the lower end, the fresh charge will reach the hot part of the tube too soon on the compression stroke and ignition will be too early. This will cause the

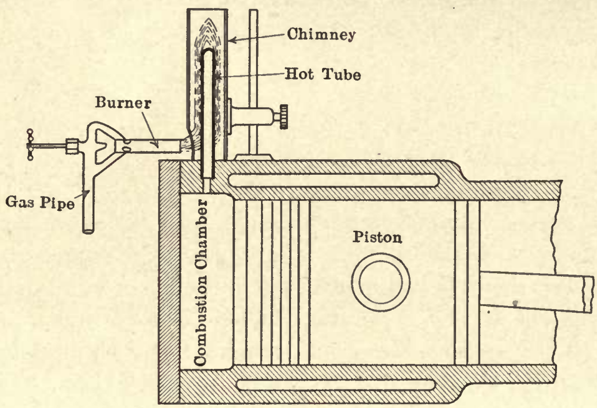


FIG. 1.—Hot-tube igniter.

explosion pressure to act against the motion of the piston during the balance of the compression stroke and will cause the engine to "pound." On the other hand, if the heating flame is too far out from the cylinder, the fresh gases may not reach the hot part and ignition may not occur. It will thus be seen that the time of ignition may be varied by changing the location of the heating flame on the outside of the tube. It may also be controlled by using tubes of different lengths, since a longer tube will permit the fresh gases to enter it farther during the compression stroke. It will be evident that this method of ignition does not offer an accurate and ready control of the time of ignition and that the matter of ignition control for starting is especially difficult, since ignition can not be retarded until after the end of the compression stroke. The common method of starting such an engine is to turn it by hand until the cylinder has been charged and then to turn it backward against the compression until ignition occurs. The engine is then driven forward by the force of the explosion, which occurs before the piston has reached the end of the backward stroke.

One difficulty with this method of ignition is that the iron or steel tubes are burned out by the action of the heating flame and by the combustion on the inside. To partially overcome this, nickel-steel tubes have been used as they resist this corrosive action longer than mild steel or wrought iron. Porcelain has also been used to some extent as it does not burn out like iron or steel.

Several minutes are required to start an engine equipped with hot-tube ignition, as the tube must first be brought to a red heat. With the advent of gasoline as a fuel for internal combustion engines this difficulty became doubly serious, as it became necessary first to generate gas for the heating flame from the gasoline before the tube itself could be heated. This led to the development of electric ignition. The advent of the automobile gave added impetus to the cause of electric ignition, as hot-tube ignition was almost out of the question for this use, although some of the early machines did use hot-tube ignition.

There were several modifications of the hot tube from that shown in Fig. 1. Some engines used a small valve to control the time at which the fresh charge was allowed to enter the tube. Others provided a small opening at the upper end of the tube to permit the escape of the dead gases and the admission of the fresh mixture into the tube. In still another form, a small tube within the hot tube led nearly to its upper end and was provided with a valve to release the dead gases from the tube at the desired instant.

3. Hot-bulb Ignition.—The hot bulb is frequently spoken of as being a modification of the hot tube. Instead of the hot tube, a large proportion of the combustion chamber is formed into a bulb-shaped cylinder head, as shown in Fig. 2. Heat is applied from without only for starting. After starting, the bulb is kept hot by the combustion occurring on the inside during the regular operation of the engine. This form is used quite generally for engines using kerosene and heavier oils, the bulb furnishing heat to assist in vaporizing the fuel as well as in igniting the mixture after it is formed.

The control of ignition in this system is effected in various ways. It is evident that the temperature of the bulb will vary with the load on the engine. Under a heavy load with full charges in the cylinder the bulb will receive more heat than under light loads. Where the bulb is depended upon for the vaporization of the fuel, this is compensated to a greater or less extent by the additional heat taken from it to vaporize the increased amounts of oil. In addition, the Hornsby-Akroyd engine shown in Fig. 2 is provided with a water jacket at the base of the bulb. By controlling the water supply to this jacket the temperature of the bulb may be regulated. In the Mietz & Weiss hot-bulb engine shown in Fig. 3 the control is effected by steam admitted to the cylinder with the charge. This steam is generated in the cylinder jacket and therefore its amount will be proportional to the amount of fuel burned in the cylinder. The addition of steam to the combustible mixture in the cylinder increases the capacity of the mixture for absorbing heat and also raises the temperature at which ignition takes place, thus requiring a greater amount of heat from the bulb at the times when the bulb is hottest.

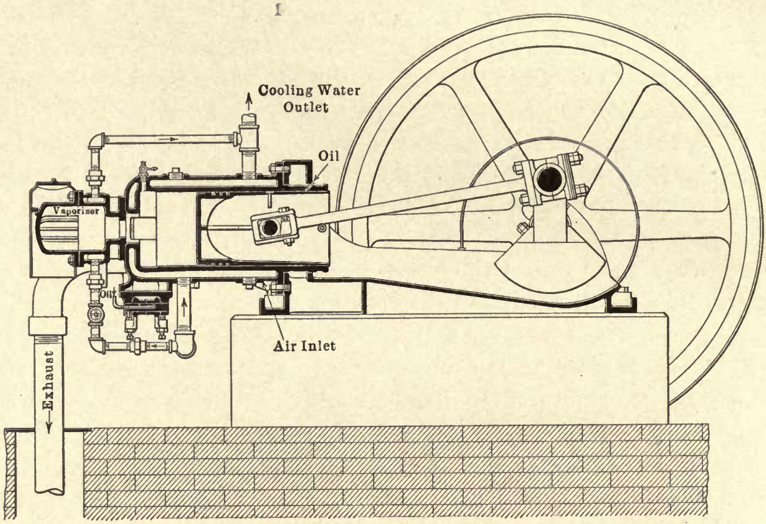


FIG. 2.—Hornsby-Akroyd oil engine.

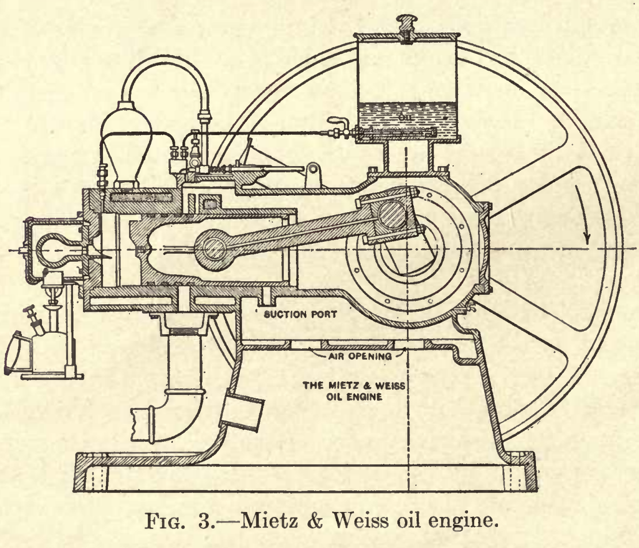


FIG. 3.—Mietz & Weiss oil engine.

There are various modifications of the hot-tube and hot-bulb systems of ignition, all based on the principle of using a hot piece of metal to ignite the charge. Among these is the hot bolt, which consists of a bolt projecting into the combustion chamber from the cylinder head or the piston head. This bolt, likewise, is kept hot by the combustion occurring around it in the combustion chamber. This device has less possibilities for regulating its temperature and the time of ignition.

4. Ignition by Heat of Compression.—When air, or a mixture of fuel and air, is compressed rapidly, its temperature rises, and if the compression is carried high enough, the temperature will become sufficient to ignite the fuel. The work put into compressing the charge is turned into heat in the charge and consequently causes the temperature of the charge to rise as the compression progresses. The more the charge is compressed the higher is the temperature raised. This phenomenon can be made use of as a regular means of ignition. The Diesel engine is the best

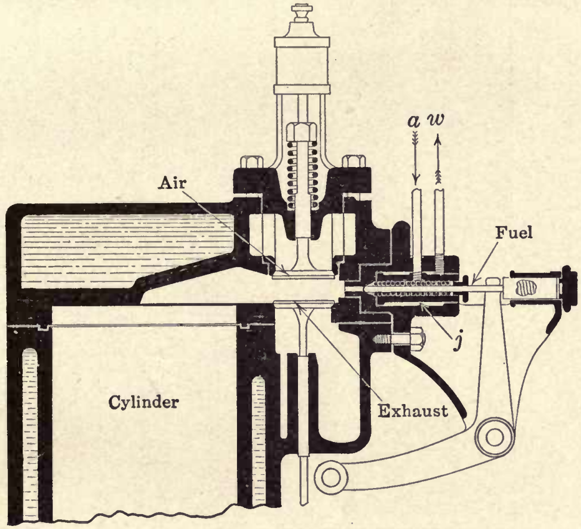
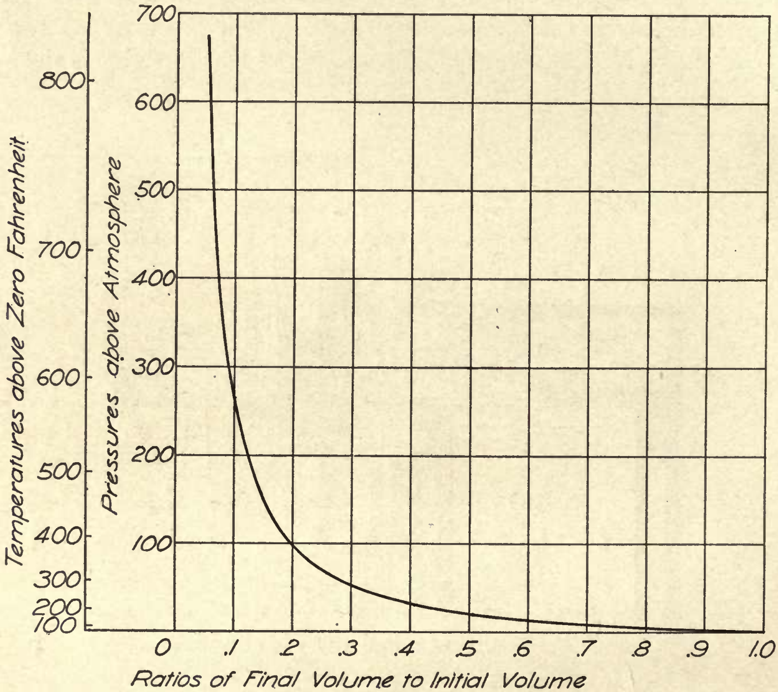


FIG. 4.—Section of cylinder of Diesel engine.

example of this. Figure 4 shows a section of the cylinder of an engine of this type. The fuel is not introduced into the cylinder until after compression is about completed and after the air has been brought to a very high temperature by the high compression. During the charging of the cylinder, only air is admitted. This prevents any possibility of ignition occurring before it is wanted and enables the ignition to be accurately timed by the fuel injection. The air is usually compressed to from 450 to 500 lb. per square inch above atmospheric pressure, thus producing a temperature in the neighborhood of 1000°F. The fuel is then injected into this "red-hot" air. It is immediately ignited as soon as it strikes this hot air and burns as fast as it is injected. This type of engine is used especially for the low-priced heavy oils. In some of Dr. Diesel's experiments, engines of this type were also operated on pulverized coal.

The diagram of Fig. 5 shows the approximate manner in which the temperature and pressure of a cylinder charge will rise as it is compressed. This curve is based on an initial atmospheric pressure of 14 lb. per square inch and a temperature of 62° when compression is started. These would be approximately the conditions of a charge in starting an engine cold. After it has begun operation, the charge will be hotter to begin with, being probably from 200° to 300°F., due to the heating which the air undergoes in going through the valves and to the amount of hot burnt gases which



Effect of Compression on Pressure and Temperature
From 14° Absolute and 62°F

FIG. 5.

remain in the cylinder and mingle with the fresh charge. As shown on the diagram, a compression of 500 lb. per square inch produces a temperature of about 740°F. from an initial temperature of 62°F. If the charge is at 200°F. at the beginning of compression, the final temperature at 500 lb. will be about 970°F., the temperature increase being greater if the initial temperature is higher. Since iron begins to show red at a temperature of about 1000°F., it will be evident that the air in the cylinder of such an engine is practically "red-hot" air at the end of compression. The engine must be designed to produce a sufficient temperature to ignite the fuel when starting under the conditions used for the diagram of Fig. 5. The ignition temperatures for the liquid fuels probably range from 360° to 800°F., although little exact scientific information is available for the different oils, and we must depend largely upon experiment to determine the compression necessary.

5. Semi-Diesel Engines.—The term "semi-Diesel" is comparatively new and is often loosely applied. It is most properly applied to engines which inject the fuel near the end of compression as in the Diesel engines, but which do not depend entirely upon the compression for ignition. Figure 6 shows a section of the Bessemer oil engine which may properly be classed under this name. The cylinder head is not water-jacketed, but is of a modified bulb type. The combustion chamber is comparatively small, giving a compression of about 180 lb. This is much lower

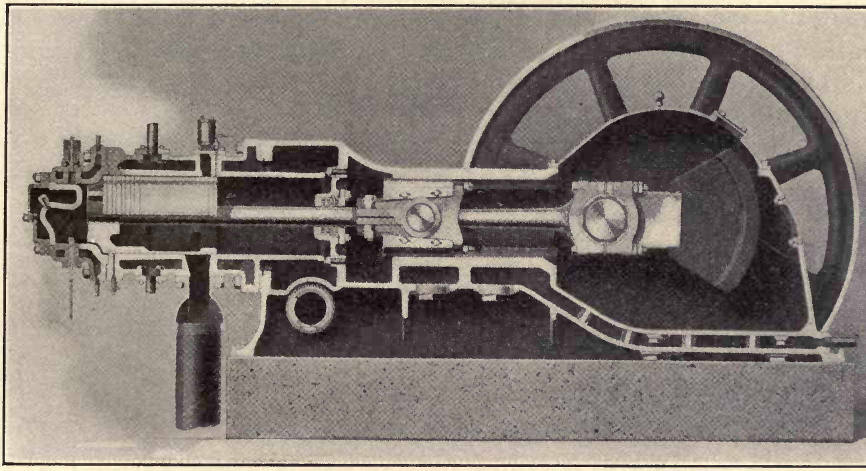


Fig. 6.—Bessemer oil engine.

than in the true Diesel type, but is more than could be used with engines which form the explosive mixture in the cylinder prior to ignition. Near the end of compression, a pump starts to inject the oil into the combustion chamber. The ignition may be said to be produced by the compression supplemented by the hot cylinder head or bonnet. The compression supplies a certain amount of heat to the air, and the hot bonnet supplies the additional heat necessary to start combustion. The cylinder bonnet must be heated before starting just as must the bulb of a hot-bulb engine, as the compression is not alone sufficient for ignition. This Bessemer engine operates on the two-stroke cycle, although this is not an essential feature of semi-Diesel engines.

In appearance there is little difference between a semi-Diesel engine and one of the older hot-bulb type of oil engines. There is, however, this real difference in operation: the hot-bulb engine forms the mixture of oil vapor and air prior to compression, and this mixture is compressed and exploded. The compression is therefore limited by the ignition temperature of the mixture. Furthermore, the combustion takes the nature of an explosion because the fuel is mixed with the air prior to ignition. The semi-Diesel engine compresses a charge of air just as in the true Diesel type, but to a lower temperature, and the fuel is injected in a similar manner near the end of compression. There may be a partial explosion in the semi-Diesel engine, since a part of the fuel may be injected and vaporized before ignition occurs, thus producing an explosive rise in pressure, but the injection and combustion of the rest of the fuel occur at practically a constant pressure as the piston is starting forward on its working stroke.

The thermal efficiency of the semi-Diesel engine will be slightly lower than the true Diesel engine, due to the lower compression and expansion ratios, but this is to some extent offset by the lighter construction permitted by the lower working pressures and by the consequent lower friction losses.

6. Electrical Ignition Systems.—At the present time, the most common means of ignition is the electric spark. There are two general systems, as follows:

1. Make-and-break.
2. Jump-spark.

The current for electrical ignition is supplied from the following sources:

1. Primary (dry or wet) cells.
2. Secondary or storage cells.
3. Direct-current generators.
4. Low-voltage, alternating-current generators.
5. High-voltage, alternating-current generators.

All make-and-break systems, when used with primary or storage cells and direct-current generators, employ the use of retardation or "kick" coils to provide the necessary spark. When these systems are supplied with current from low-voltage alternating-current generators (usually "magnetos") no "kick" coil is necessary, as the winding of the generator serves as a "kick" coil.

Jump-spark ignition is by far the more extensively used system, due to its general use for automobile and motor-boat engines. In this system, an electric current is caused to jump from the insulated electrode of a spark plug to the framework of the engine. This spark takes place at the proper time in the presence of compressed fuel and air in the combustion chamber. As a result, the mixture is ignited and exploded.

Combinations of equipment required for jump-spark systems are as follows:

1. Vibrating or non-vibrating coils with dry or storage cells, or direct-current generators.

2. Non-vibrating coils with mechanical interrupters and with dry cells or low-tension magnetos.

3. High-tension, alternating-current generators, with or without dry cells.

In the above-named systems, many different combinations exist. For automobile use, the main sources of ignition current are storage batteries and low- and high-tension magnetos, while dry cells are almost entirely used for starting and auxiliary purposes. For stationary engines, dry cells, wet cells, and magnetos are used, as well as current from ordinary lighting circuits.

7. The Make-and-break System.—This is the simplest form of electrical ignition, since it requires but three essential parts, viz., a source of current, a "kick" coil, and an igniter. Until recently it was standard

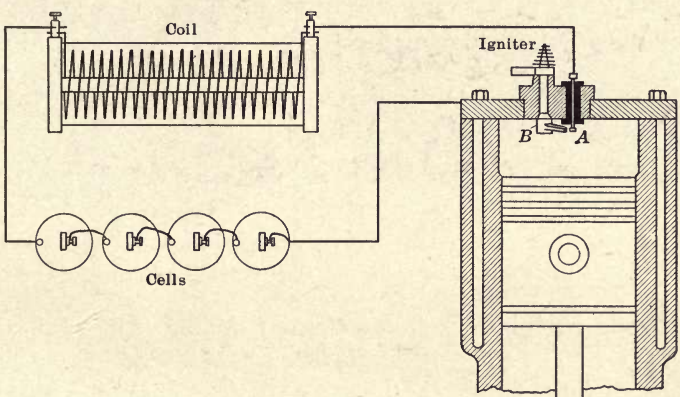


FIG. 7.—Wiring diagram of make-and-break system.

practice to equip small cylinder engines with this system, using dry cells to supply the current. During the past few years, there have appeared on the market a large number of low-priced electric generators which are growing in favor for this type of engine.

A typical wiring diagram for a make-and-break system is shown in Fig. 7. In this type, part of the electric circuit is within the combustion chamber, with an outside arrangement for making and breaking the electric circuit inside the cylinder. At the proper time, the two contact points are brought together and the circuit completed so that current will flow. When the desired piston position is reached, the contact points within the cylinder are separated quickly, causing a spark to leap the gap produced in the circuit as these points separate. The resulting spark ignites the mixture of air and gas at the time of highest compression. On engines having high compression the make-and-break system is especially desirable. Jump-spark systems are not generally reliable for compressions of 150 lb. or more because the compression increases the resistance of the gap to the passage of the spark.

8. "Kick" Coils.—The type of coil used with make-and-break systems is known to the trade by names such as *spark* coil, "*kick*" coil, *reactance* coil, *single-winding* coil, and *retardation* coil. This coil consists essentially of a continuous winding of several layers of insulated copper wire wound around a bundle of very soft iron wires. For the sake of convenience, and to suit different conditions, the coils are made in various forms. Some engines are exposed to dampness, in which case the coil is enclosed in a waterproof casing. Figure 8 shows a "kick" coil having a cylindrical casing which may be either of fiber or sheet metal. The winding consists of from four to six layers of about No. 16 or No. 18 gage

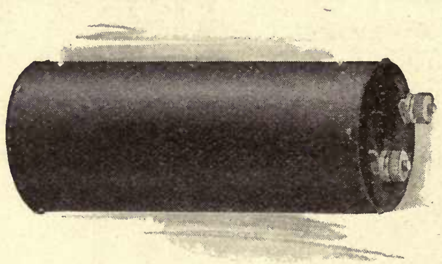


Fig. 8.—Pfanstiehl tubular coil.

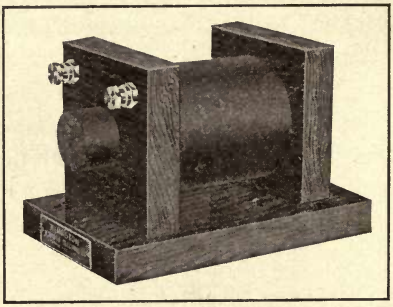


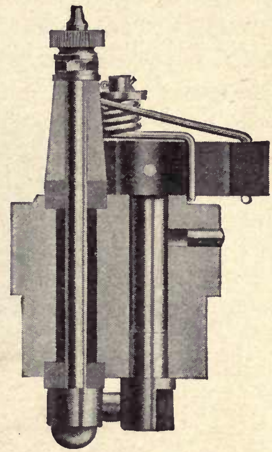
Fig. 9.—Kingston make-and-break coil.

insulated copper wire, wound on a circular bundle of fine annealed Norway iron wire. The ends of the winding are well secured to a fiber disc. The final step in the making of the coil consists of filling the tube in which the winding is placed with an insulating compound which is impervious to moisture. The winding has an approximate resistance of 1 ohm, the "ohm" being the unit of resistance to the flow of electric current. One of the main features of this coil consists in its size, which is the same as that of a dry cell, 2½ in. in diameter by 6 in. long. This appeals to the trade, for the coil can be installed in the battery box.

The block type of coil is shown in Fig. 9. The windings are large in size and are covered with waterproof material to keep out moisture.

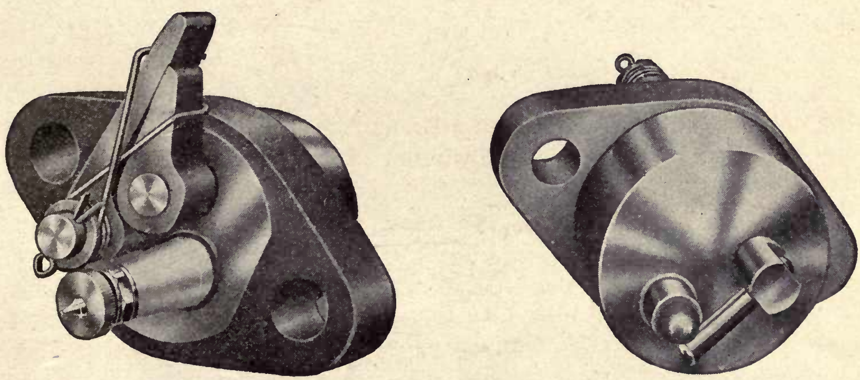
9. Igniters.—Every make-and-break system is equipped with a mechanical igniter consisting of one stationary and one movable electrode. It is self-contained in one substantial casting, the wearing surfaces being case-hardened. Figure 10 shows an igniter as made by the International Gas Engine Co. The stationary or fixed electrode is insulated from the main casting by thick mica washers and is held in place in such a manner that by loosening a lock nut the special metal ring of the fixed electrode may be turned from time to time, exposing a new sparking surface. The movable electrode contains a contact arm of special metal which is securely fastened to the movable electrode shaft. The upper view shows a longitudinal section through the igniter.

The arrangement of the igniter in the cylinder head is shown in Fig. 11. The igniter push-rod is operated from the camshaft, revolving at one-half the speed of the crankshaft. There are two springs on a make-and-break igniter. One spring between the trigger and the movable electrode allows the trigger to be moved beyond the point where it brings the two electrodes into contact. The other spring, between the frame and either the trigger or the movable electrode, breaks the circuit when the trigger is released from the push-rod and throws the electrode back into its open-circuit position.



SECTION

In the igniter shown in Fig. 11, the timing of the ignition is varied by a lever which is arranged to raise or lower the push-rod and thus change the time at which the push-rod releases the igniter trigger. Another means sometimes used for changing the time of ignition is to turn



OUTER END INNER END

Fig. 10.—The "Ingeco" igniter.

or shift the whole igniter in its seat, thus shifting the position of the trigger with respect to the push-rod. This does not permit of changing the timing while the engine is running, as does the method shown in Fig. 11.

Another form of igniter, known as the wipe spark igniter and made by the Foos Gas Engine Co., is shown in Fig. 12. In the previous type, the contacts were made to touch without any rubbing. The Foos igniter, as shown in this cut, consists of two independent electrodes, each carrying a steel blade with a surface about ½ in. long. The movable blade *A* wipes against the edge of the stationary insulated spring *B* at the proper interval and produces at the break an electric spark of high temperature. At

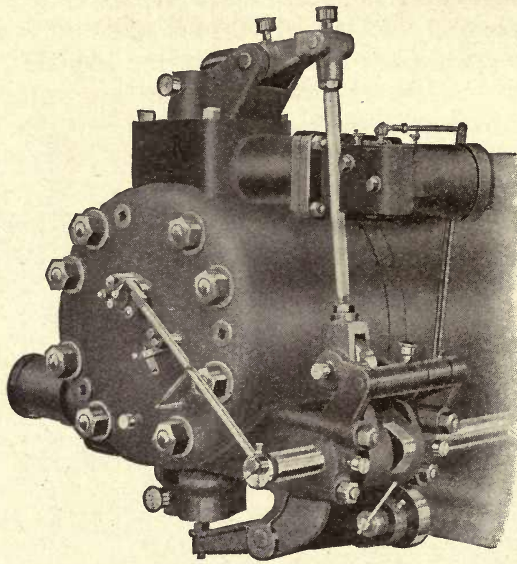


FIG. 11.—"Ingeco" cylinder head, showing igniter and trip rod.

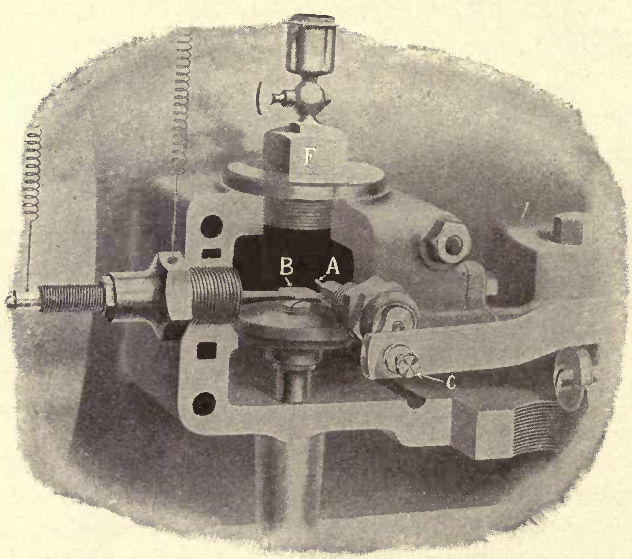


FIG. 12.—Foos wipe-spark igniter.

the same time, the wiping contact of the two electrodes removes any burnt carbon or scale and keeps the points brightly polished, insuring even ignition. Adjustment for wear of the blades is made by loosening the lock nut on the stem of the spring *B* and moving this spring toward the revolving blade *A*. The time of ignition is adjusted by turning the thumb screw *C* in the end of the igniter rod. The movable electrode revolves in graphite bushings, thus dispensing with the use of lubricating oil.

An effort has been made by the National Gas Engine Association to standardize certain parts of gas engines. Figure 13 shows their standard dimensions for the stationary electrode. The stem is insulated with rolled mica, which does not have any upturned edges in the combustion chamber and which is, therefore, free from short-circuits. The taper arrangement makes it impossible for the insulation to loosen or pull out.

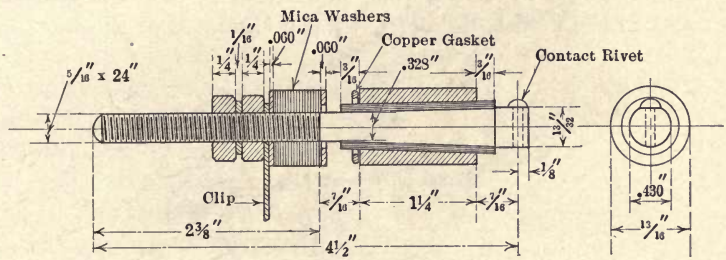


FIG. 13.—N. G. E. A. standard fixed electrode.

10. Igniter Points.—Owing to the fact that the igniter points are subjected to the high heat of the electric spark and also to constant hammering as the circuit is closed, a great deal of difficulty has been experienced in finding a suitable metal. Platinum and iridium have been used considerably in the past. Platinum withstands the heat, but is soft and does not hold up under the hammering of the points. Iridium is very hard and difficulty is experienced in making it into the form required for the points and in fastening it in place. An alloy of these two metals containing about 20 per cent iridium is largely used. This has the desired hardness and resistance to heat, but is very expensive. Owing to this high cost of platinum and of alloys containing platinum, points made of steel or of special alloys of steel with other metals such as nickel or tungsten are now widely used. They are usually made in such form that they can be easily and quickly replaced.

11. Operation of a "Kick" Coil.—The coils in make-and-break ignition systems are usually operated by current from chemical cells or direct-current generators. A number of make-and-break systems employ a low-voltage, alternating-current generator, in which case no coil is necessary, as the winding of the generator armature serves that purpose.

Figure 14 shows a simple diagram of a "kick" coil. The igniter is omitted from this circuit. The alternate heavy and light lines near the bottom of the figure show the conventional method of representing a battery in wiring diagrams. The coil is shown as a single winding of wire, although an actual coil would be wound with several layers of closely laid insulated wire. Within the coil is a core of soft iron. When a current of electricity is passed through the coil winding, the core becomes magnetized and has all the properties of a bar magnet. As soon as the current is shut off, the core, if of soft iron, will lose its magnetism. When the core is "energized," one end of a compass or any other bar magnet will be attracted by one end of the core and repelled by the other end. The light lines radiating from the ends of the core in Fig. 14 indicate in a general way the direction and intensity of the magnetic field. If a compass were held at any point near the coil, the needle would point in the direction indicated by the lines in the figure. The intensity of the magnetic force at any point in the field is indicated by the closeness of the lines to each other.

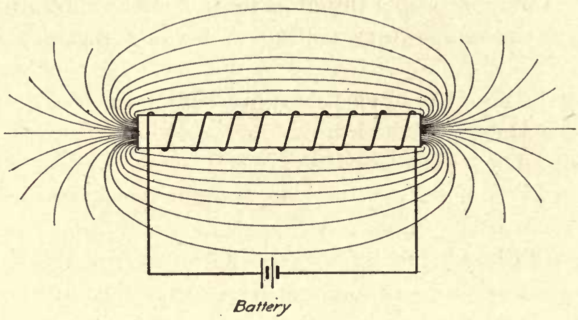


FIG. 14.

When an electric circuit is completed through a straight length of wire, the current will rise almost instantly to its full value, that is, to such value as the resistance of the wire will permit. On the other hand, if the wire is coiled about an iron core so that the core must be magnetized, an appreciable length of time elapses before the current reaches its full value. It might be said that the growing current is "choked" or held back by the opposition which the iron offers to being magnetized. It takes energy to create the magnetic field, and anything which requires work takes time. An automobile engine may be capable of driving a car at 60 miles an hour, but it will take it some time to bring it up to that speed. The building up of the field of the coil might be likened to the building up of the speed of the automobile. It takes energy to do it and, when the power is turned off, it will not stop until the energy has been taken out or given back. In the automobile we have to use the brakes to take out this energy before the car will stop. In the ignition coil the energy used to energize the core is made use of to produce the desired spark.

When the current is cut off, by breaking the electric circuit, the current will not stop instantly. The magnetic field in dying out gives back its energy into the coil and produces a current in the same direction as the original current and thus tends to prolong the flow.

This might naturally be expected; if the iron core resists being magnetized and holds back the current when the circuit is closed, it would be expected also to oppose the stopping of the current and tend to keep up the flow. In reality, when the magnetic field in a coil is strong and the circuit is suddenly broken, the voltage induced in the coil winding by the dying magnetic field is considerably higher than the original voltage of the battery. It is this high-voltage induced current which produces the spark at the igniter points in a make-and-break ignition system. The battery current merely serves to magnetize the coil when the circuit is closed. Electrical energy is stored in the form of magnetism when the field is built up; it is given back as electricity when the circuit is broken.

The voltage of the battery used is usually 6 or 7 volts. When a tripping mechanism of proper design is used, so as to separate the contact points quickly, the momentary voltage at break sometimes runs as high as 300 volts.

Voltage is the measure of electrical pressure, like the pressure of water in a pipe, and is the force which tends to move the electricity.

The action of a "kick" coil may be likened to some extent to the "water hammer" in a water pipe. If we open a valve suddenly, the inertia of the water in the pipe must be overcome before the water can be set in motion and flow from the valve. After the water is flowing, if the valve is closed suddenly the momentum of the long column of water in motion will produce a terrific blow when it is stopped so quickly. The instantaneous pressure produced by the water hammer may be several times that of the ordinary pressure of the water which set up the motion when the valve was opened.

The effect of a coil in a circuit may be observed by two very simple experiments. First, connect a wire to one terminal of a battery and touch the other end of the wire to the other terminal of the battery and observe the weak spark that will be produced. Next, connect the coil in the circuit and then make and break the circuit in the same manner. A much larger spark will be observed.

The coil core is made of small wires of soft annealed iron because a large single bar is not as easily magnetized and the magnetism will not disappear as quickly as in the small wires. The same is true of harder steel or iron as compared to the soft iron. The voltage at the break of the circuit depends largely on the condition of the core in this respect.

12. Igniter Design.—The chief points to be observed in igniter design are a good contact at the igniter points, a duration of the contact sufficient only to allow the current in the coil to reach a maximum value, and a tripping mechanism that will cause a very sudden separation of the points. The tripping points should, of course, be case-hardened to withstand the wear on them.

The igniter points deteriorate because of the hammering effect when the circuit is closed. Owing to the fact that an electric arc of about $\frac{1}{16}$ in. is drawn out between the points when they separate, the heat of the arc distintegrates the points, and the continual sparking causes them to be worn away. In addition, there is a sort of electrolytic action, similar to that which takes place when a current flows through an electroplating bath. At each break of the circuit the current travels from one electrode to the other and particles of metal are taken from the one and deposited on the other. This effect can be greatly reduced if the battery is reversed through the circuit. Impurities in the igniter points will also contribute to their wearing away.

Since current flows in the ignition circuit during the time the igniter points are in contact, the duration of contact should be made just long enough for the current to build up to a maximum. Any longer flow will

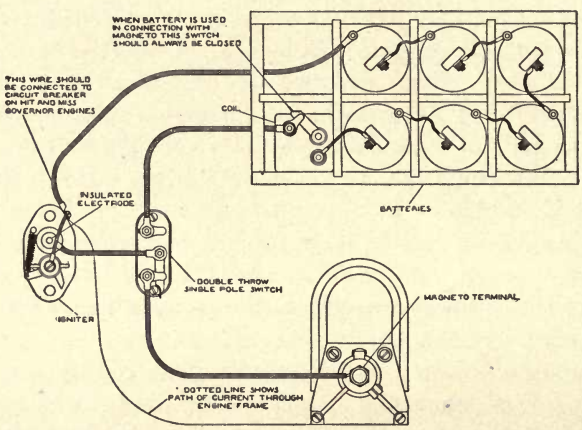


FIG. 15.—Make-and-break system with both battery and magneto on single cylinder engine.

merely waste the batteries. Because of the choking effect of the coil, following the rush of current, a small interval of time elapses between the closing of the circuit and the point of maximum current. The time required for the current to reach a maximum depends primarily upon the number of turns of wire in the coil and on the size and quality of the core. The average time required is about 0.02 second.

13. Make-and-break Circuits.—Figure 15 shows a typical wiring diagram for a make-and-break system using batteries and coil for starting and a magneto for running. This scheme is usually employed in the larger engines which can not be turned fast enough by hand to produce a sparking current with the magneto. In starting, the switch is thrown to battery position. When the igniter points make contact, the path of the current can be traced from the carbon or positive pole of the battery, through the "kick" coil to the insulated electrode, thence to the framework of the engine and back to the zinc or negative terminal of the battery. After the engine is started, the switch can be thrown to magneto position (shown in diagram) after which the magneto furnishes the current for ignition.

If a direct-current magneto is used, it can be belt-driven or friction-driven, since it produces a current of uniform strength at all points in its revolution.

When an alternating-current magneto is used, the armature must be in a certain position when the igniter points open, because the value of the current varies with the position of the armature. This necessitates having the armature of the magneto gear-driven from the engine shaft, so that the position of the armature will always be in the same relative position to the shaft and, hence, also to the piston position.

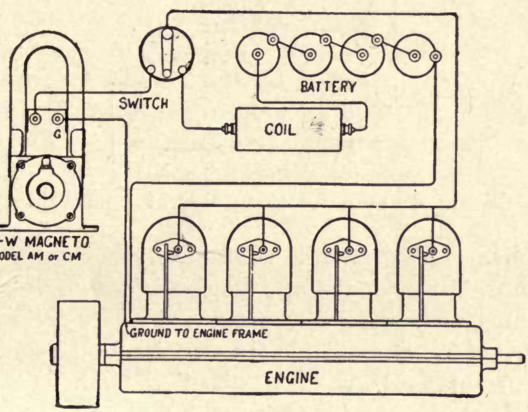


Fig. 16.—Make-and-break system with both battery and magneto on four-cylinder engine.

14. Multi-cylinder Circuits.—The wiring of multi-cylinder circuits is similar to that of single-cylinder engines, the same coil and batteries being used for all cylinders. Figure 16 shows an arrangement for a four-cylinder engine using dry cells and a kick coil for starting and a low-tension magneto for running. When running on the battery, all the igniters get their sparking current from the same coil and battery. The igniters are normally open. When the circuit is closed at one of them the current will flow through that particular igniter. When the igniter trips, the spark occurs at that igniter. The winding of the magneto acts as its own coil. Hence the magneto may be connected direct to the make-and-break igniters. This action of the magneto will be explained in a later chapter.

Figure 17 shows an arrangement for securing ignition current from a lighting system, with an auxiliary source consisting of dry or wet primary cells for emergency use. The usual lighting circuit is of 110 volts, and to connect such a voltage to the ordinary coil which is designed to operate with perhaps 5 or 6 volts would be destructive to the coil, as an excessive current would flow through the coil. Hence, the lamps shown in the figure are used to control the current and allow only the desired amount to flow through the coil. A 16-c.p. carbon lamp will pass ½ amp., so that the three lamps shown in the figure would give a current of 1.5 amp., which is about the desired amount. The number of lamps may have to be varied

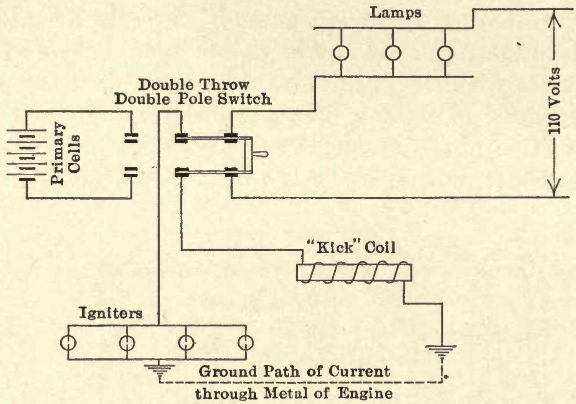


FIG. 17.—Wiring diagram for using current from lighting circuit.

for different coils. This system is wasteful of electricity, as most of it is used in the lamps, but even at that, the cost of the current used, at ordinary lighting rates, would be less than the cost of dry-cell current. When the lighting current is not available the switch may be thrown to the left and dry-cell current used.

The small inverted pyramids of lines below the igniters in this diagram represent "grounds," that is, the points between which the metal of the engine is used for the current path instead of having a complete circuit of wire. The broken line between the two grounds represents the path of the current from one ground, through the metal of the engine, to the other ground.

CHAPTER II

JUMP-SPARK BATTERY SYSTEMS; VIBRATING COILS

15. The Jump-spark System.—The make-and-break system described in the preceding chapter has certain disadvantages which make it especially undesirable for high-speed engines. The mechanical operation of the movable electrode at very high speeds would involve certain difficulties and would produce considerable noise. The weight of the push-rod and the other parts to be moved and the rapid speed required would be very hard on the construction of the mechanism. These points have naturally influenced the selection of the jump-spark system for high-speed use. In this system, a fixed spark gap is provided in the combustion chamber, by a spark plug made up of two fixed electrodes or terminals, one insulated from, and the other in contact with, the metal of the cylinder. Battery current is transformed by an induction coil into a current of very high voltage which leaps across the gap at the spark plug and thus produces a spark to ignite the mixture.

The use of the jump-spark system is generally limited to engines having low or moderate compressions. In high-compression engines (150 to 200 lb.) the compressed charge offers a great resistance to the passage of the spark between the points, and an adequate spark can only be produced by a specially constructed coil capable of producing and withstanding the necessary high voltage.

The devices which are used to supply the high-voltage ignition current for jump-spark systems by transforming it from a low-voltage supply, such as primary or storage cells, are called induction coils and are divided into vibrating and non-vibrating coils. The vibrating coil delivers a shower of sparks at the gap in the plug, whereas the non-vibrating coil delivers but one spark for each ignition.

16. Vibrating Coils.—The essential parts of a vibrating coil are a core of soft iron wires, a primary winding of coarse insulated copper wire, a secondary winding of fine insulated copper wire, a condenser, and a vibrator.

In Fig. 18 is shown a diagram of a simple circuit for a jump-spark ignition system with a vibrating coil. There are two separate and distinct electrical circuits shown here, although in practice some parts of the two circuits may be combined, as will be seen later. The primary or battery circuit includes the battery, the timer, the primary winding of the coil, the vibrator, and the condenser. The secondary circuit contains the fine or secondary winding of the coil and the spark plug. When the primary circuit is completed at the timer (which is usually on, or connected to, the camshaft of the engine), current from the battery will flow through the primary winding of the coil. The core of the coil thus becomes magnetized, and so long as the current flows this core will have the properties of a magnet. The core exerts a pull on the iron disc or armature attached to the end of the vibrator and in so doing separates the contact point on the vibrator from the stationary contact. This breaks the primary circuit and the current ceases to flow. The core therefore loses its magnetism and the vibrator returns to its former position. In so doing, it reëstablishes the circuit and the action is repeated. Thus we see that so long as the primary circuit is closed at the timer the armature or vibrator will vibrate rapidly, just like the vibrator of an ordinary electric doorbell.

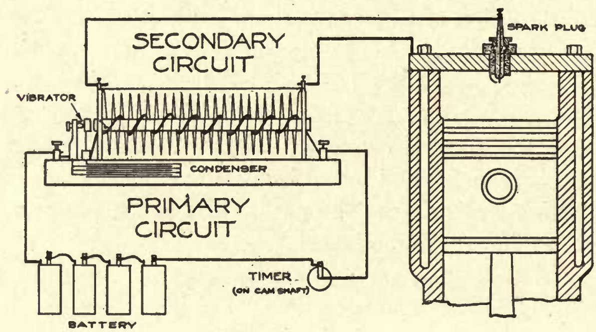


FIG. 18.—Jump-spark system of ignition.

In a great many respects this primary action is seen to resemble the action of the make-and-break system. The development of the magnetism in the core is not instantaneous but requires an appreciable time for the magnetic field to rise to a maximum. When the armature is drawn to the core and the circuit is broken, the magnetic field dies away very quickly and a spark would be produced at the vibrator points just as at the igniter of the make-and-break system if it were not for the condenser, which is a device for absorbing this induced current in the primary and assisting in the sudden destruction of the magnetic field of the core. The construction and operation of the condenser will be taken up separately later in this chapter.

As before mentioned, when the vibrator breaks the circuit of the primary current, the magnetic field of the core is rapidly destroyed and this induces a current in the primary winding which surrounds the core, just as explained in connection with the make-and-break system. Since the secondary winding also surrounds this same core, a current will also be induced in it at the same time. The induced pressure or voltage in any coil depends largely upon the number of turns in the coil and upon the rapidity with which the core is magnetized and demagnetized. By having several thousand turns of very fine wire in the secondary coil we can produce a current of exceedingly high voltage in this coil. This high voltage causes a current to leap the gap in the spark plug and thus to produce the spark. It will thus be seen that the primary winding and its current are used for magnetizing the core, while it is the induced current of the secondary coil that is used for the spark, this current being induced when the primary circuit is broken.

A current is induced in the secondary when the magnetism is being built up as well as when it is destroyed, but, owing to the fact that the magnetism builds up slowly, the induced pressure at this time is negligible. However, at break the induced pressure is large, due to the rapidly dying magnetic field. The shower of sparks appearing at the spark plug terminals then is a series of sparks occurring only each time the primary circuit is broken.

17. The Primary Winding.—The core on which the primary winding is placed is made up of a paper tube about ¾ in. in diameter and about 6 in. long, filled with about No. 20 gage soft iron wires. The wires are annealed to make them as soft as possible so that they can be easily magnetized and rapidly demagnetized.

The primary winding is usually made up of two layers of insulated copper wire, ranging in size from No. 16 to No. 20 B. & S. gage. The insulation of the wires consists of two layers of cotton fiber, though in some cases an enamel insulation is used instead. As moisture is an enemy to any electrical device, the core and winding are treated with paraffin or some other insulating and moisture-proof compound by a special impregnating process.

18. The Secondary Winding.—The secondary or high-tension winding of an induction coil is made up of thousands of turns of enameled or silk-covered copper wire, usually about No. 36 B. & S. gage. The winding is sometimes made up of several layers each running the entire length of the coil. Another construction is to have the winding made up of several narrow spools or "pancakes" which are assembled over the primary element with suitable insulation between them. The adjacent ends of these pancake coils are then connected so that their windings will be in series.

The reason for this construction is as follows: The secondary winding of an induction coil used for gas-engine ignition produces a pressure of 10,000 to 20,000 volts. This means that the quality of the insulation and construction must be very high to prevent this induced current from escaping at some other point than at the spark-plug gap. A current at a pressure of 10,000 volts will leap through a gap of nearly ½ in. in the open air. Each turn of the winding develops its share of the voltage of the whole coil. In coils where the winding is made in long layers, the full voltage developed exists between the top and bottom layers. One can see, then, that there is a chance for the spark to leap between layers, which, of course, must be prevented by high-quality insulation. It is standard practice to run a layer of thin waxed paper between the layers of wire and to impregnate the whole winding with wax. In this way the coil is not affected by dampness and there is less chance for the coil to break down due to defective insulation. By breakdown of the secondary winding is meant a flow of the current between layers of the winding, causing an arc within the coil instead of at the desired point where the spark is wanted. In pancake windings, the terminals of the secondary coil are separated the full length of the coil and the voltage difference between the successive reels or pancakes is only a fraction of the total voltage.

The secondary winding of a coil should also be well insulated from the primary winding. For this a material having a high dielectric or insulating strength should be used. The best dielectric materials are glass, mica, rubber, paraffined paper, "empire cloth," porcelain, etc. For this particular purpose empire cloth is particularly suited, having a high dielectric strength and being flexible and quite thin.

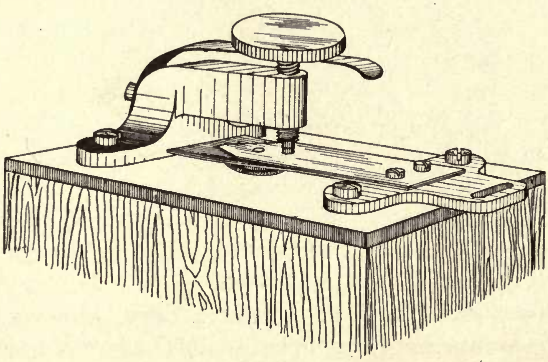


FIG. 19.—Kingston vibrator.

19. The Vibrator.—The purpose of the vibrating element in the primary circuit is to open and close the primary circuit rapidly. One end of the primary coil is attached to the vibrator. The battery current is brought to a fixed electrode or contact point on a frame back of the vibrator. The contact points of the fixed electrode and the vibrator are of special metal, so located that they make good contact when the vibrator is in its normal position. Many different forms of vibrators are used having different features, but the fundamental principle involved is the same in all. Figure 19 shows a sketch of one type of Kingston vibrator. The vibrating spring is made of tempered steel. A disc of soft iron is riveted to this spring. This disc is attracted by the core of the coil when the core is magnetized. The disc must be soft so that it also will lose its magnetism and not cling to the core when the circuit is broken. The vibrators are provided with adjusting screws by which the gap between the contact points or the tension of the spring can be adjusted. Figure 20 shows a style of vibrator used on the Pfanstiehl coils. The contact points on the vibrator and the fixed electrode must be of a metal that will not be rapidly destroyed by any sparking action, although the tendency to spark is reduced by the use of the condenser. For these points metals are used similar to those used for the sparking points in make-and-break igniters. Platinum or platinum-iridium are considered the best metals for this purpose. An alloy of nickel and steel is also used.

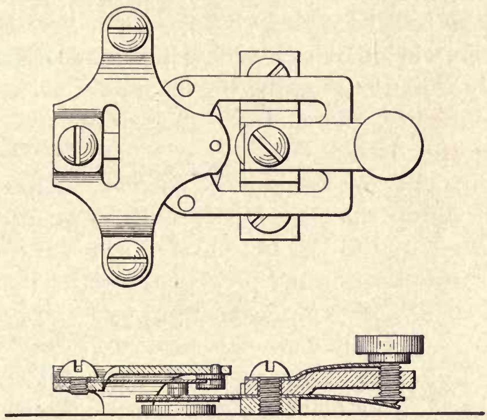


Fig. 20.—Pfanstiehl vibrator.

20. The Condenser.—We have seen that the action of the primary circuit is similar to that of the make-and-break system of ignition and that there is the same tendency to spark at the vibrator points as at the igniter points of the make-and-break igniter. This is prevented and the action of the coil greatly improved by the use of the condenser. When the circuit is broken at the vibrator, the magnetism of the core tends to oppose the stoppage of the current and the consequent destruction of the magnetism. This results in a current being induced in the primary winding in the same direction as the original current, thus tending to keep up the flow. Since the voltage of the secondary winding depends on the rapidity with which the magnetism of the core is destroyed, the flow of this current should be prevented. If this induced current in the primary flows at all it must arc across the open vibrator points. If this can be prevented and the current stopped, the magnetism of the core will collapse very rapidly and produce the greatest possible effect in the secondary winding. The vibrator points will also be protected from the harmful effects of the arcing.

This effect is brought about by using a condenser to absorb the induced current in the primary. As shown in a diagrammatic way in Fig. 18, the condenser appears to be made up of a number of thin sheets alternately connected to the fixed electrode and to the vibrator, but having no connection between the adjacent sheets. In actual practice these sheets are of tinfoil separated by oiled paper. Part of them are connected to the fixed electrode and the others to the vibrator. There is, however, no electrical connection between these two points through the condenser. When the break of the circuit occurs, the induced current which would otherwise spark across the vibrator points flows into this condenser, where it spreads out over the surfaces of these tinfoil sheets. As the magnetism dies down, the condenser discharges back through the primary winding and, as this backward surge is opposite in direction to the original current, this assists in quickly reducing the magnetism of the core to zero, thus greatly aiding in securing the maximum voltage in the secondary winding. In reality, the current surges or oscillates to and fro from the condenser and finally dies out.

In the preceding chapter, the induced current was likened to the water hammer in pipes when the flow is suddenly stopped. The condenser can likewise be compared to the air chamber which is frequently used to receive the surge of the water and prevent the water hammer.

In the actual construction of a condenser, two strips of tinfoil about 5 in. wide and 5 ft. long are rolled up with oiled paper between them. Wire terminals are soldered to the two pieces of foil. After rolling, they are usually flattened to fit into the base of the coil and the whole impregnated with paraffin wax. One of the terminals is then connected to the vibrator and the other to the fixed electrode. As the plates of the condenser are subjected to a pressure of about 300 volts, it is necessary to have a good dielectric material between them in order that no connection between the plates may occur through a puncturing of this material. If a coil sparks badly at the vibrator points it is usually evidence of the fact that the condenser has become disconnected or has broken down.

The actual number of square inches of tinfoil used in a condenser depends on the size of the windings, the quality of the iron in the core, and the speed of the vibrator. It is usually determined experimentally, that capacity which gives the best ignition current being used. The capacity of a condenser depends on the size, number, and arrangement of the plates, and upon the thickness of the dielectric material between the plates.

21. Spark Plugs.—By means of the spark plug, the current induced in the secondary winding of an induction coil is made to jump a gap inside the combustion chamber of the engine and thus produce an electric spark and ignite the charge. The essential parts are: a metal shell which is threaded to screw into a tapped hole in the cylinder wall and which also carries an electrode or point at its inner end, a central electrode of wire, and an insulator, usually of porcelain or mica. Figure 21 shows a spark plug partly in section. One end of the secondary winding of the coil is brought to the binding post of the plug and thus to the central or insulated electrode. The other end of the secondary winding is grounded to the metal of the engine. Since the central wire of the plug is insulated from the shell by the insulating material, the only path for the current is to jump from the end of the central electrode to the fixed electrode on the body of the plug and thus complete its path through the metal of the engine and back to the coil through the grounded wire.

There are two general types of spark plugs, characterized by the shape of the insulator—the petticoat and the conical types. The conical type is shown in Fig. 21, the porcelain insulator being in approximately a conical shape at the lower end. The petticoat type is shown in Fig. 22.

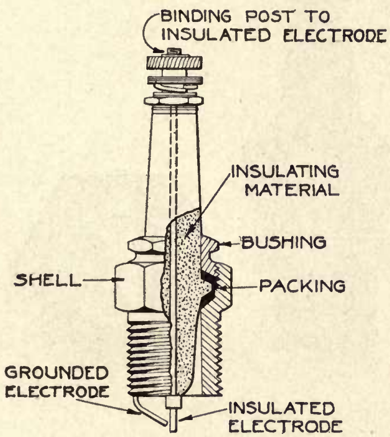


FIG. 21.—Section of spark plug.

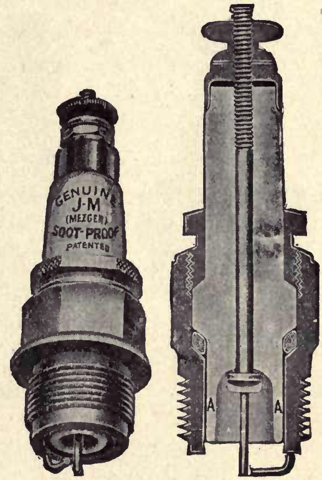


FIG. 22.—J-M soot-proof spark plug.

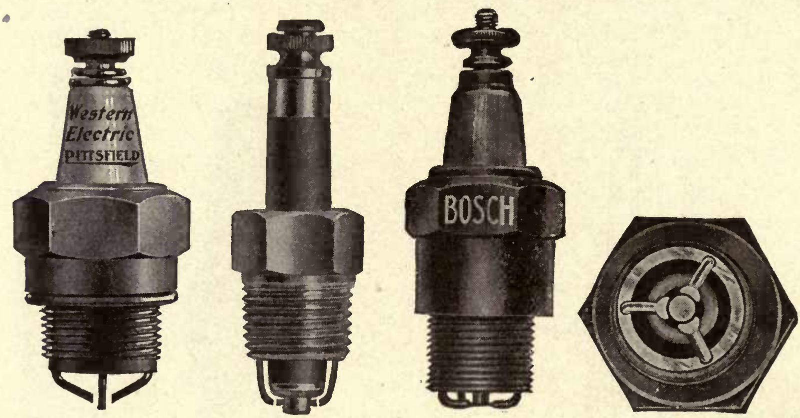
The manufacturers of this type claim for it the advantage of its being more difficult for the current to sneak through carbon deposits on the porcelain, as the surface between the points is increased. When the porcelain surface inside the plug becomes coated with a heavy deposit of carbon, the current of electricity will flow through the carbon coating instead of jumping through the gap.

Some plugs are made with a single grounded electrode; others are made with two or more. Certain advantages are claimed for multiple-point plugs, chief of which is a surer spark. In time, the gap gradually widens, due to a burning of the points. Consequently, a single-point plug will need adjustment of the gap from time to time. In the case of plugs with several grounded points, the electrodes will not burn up as fast, and therefore require less attention.

A good serviceable plug will not short-circuit, leak, or break down. Short-circuiting is produced by a deposit of carbon on the porcelain or mica element. This usually is caused by either a rich mixture or lubricating oil, or both. Good spark plugs are so assembled as to be gas-tight. This necessitates using good copper or asbestos gaskets of durable construction, since it becomes necessary to disassemble the plugs from time to time for the purpose of removing carbon deposits. The insulation must be of high-quality material to confine the electrical current to the insulated electrode. Any current leakage through the porcelain or mica renders the spark plug worthless.

Figure 22 shows the construction of the J-M (Mezger) soot-proof spark plug. The porcelain insulator is in the form of a "petticoat."

Figure 23*A* shows a Western-Electric-Pittsfield plug with double gap and a porcelain insulator. Figure 23*B* shows another two-point plug



A *B* *C*

FIG. 23.—Types of spark plugs.

made by the same concern, but with a mica insulated electrode. The construction consists of a heavy pure mica tube covering the electrode, over which mica washers are assembled under heavy compression. These plugs are very serviceable in air-cooled engines, and in engines that do not have a water jacket around the plug seat. They also make a porcelain-mica plug which combines the high insulating qualities of the porcelain plug inside of the cylinder and the flexible mica protection against possible mechanical injury outside of the cylinder. Figure 23*C* shows a Bosch plug with three points.

22. Timers.—The purpose of the timer is to close and open the primary circuit of each of the coils at proper intervals. Figure 24 shows a timer for a four-cylinder engine. The numbered terminals are connected to the primary winding of each of the coils, there being a coil for each cylinder. The interior portion is an extension of the camshaft which revolves at one-half crankshaft speed. The outer casing, to which is attached the spark control lever, can be shifted through a wide angle.

This arrangement permits the advancing and the retarding of the spark. As the roller revolves, it establishes contact between the insulated segments and the metal of the engine. This operation completes the primary circuits in succession, which in turn induces a current in the secondary windings, causing an arc at each spark plug in proper order.

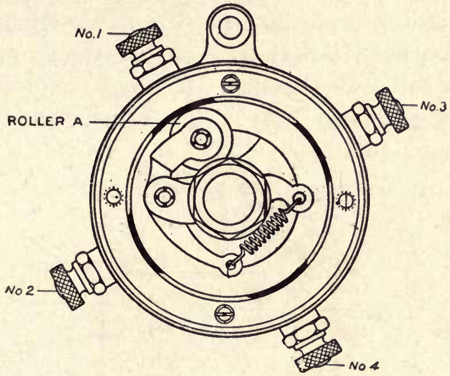


FIG. 24.—Roller-contact timer for four-cylinder engine.

There are many forms of timers, but the principle involved is the same throughout. Since the timer, or commutator as it is sometimes called, is located in the primary or low-voltage circuit, it must be designed so that good contact is made between roller and segments.

Figure 25 shows a Long Bros. roller-type marine timer for a six-cylinder engine. The rotating element is gear-driven by the camshaft

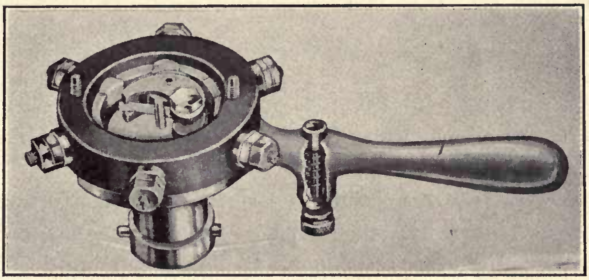


FIG. 25.—Timer for six-cylinder marine engine.

and revolves at one-half crankshaft speed, if on a four-stroke engine. The timer is provided with a handle for varying the time of ignition. This type of timer is made also for one-, two-, three-, and four-cylinder engines, the only difference being in the number and location of the segments.

In systems using vibrating coils it is customary to install one coil for each cylinder. The same types of coils and timers can be used for four-stroke and two-stroke engines. Owing to the fact that there is an explosion each revolution in each cylinder of a two-stroke engine, the arm of the timer must revolve at crankshaft speed. In the four-stroke engine the timer revolves at one-half crankshaft speed, or at camshaft speed.

23. Types of Vibrator Coils.—In the coil diagram of Fig. 18 the circuits of the primary and secondary windings were entirely separate and there were four binding posts on the coil. This arrangement was used for the sake of clearness, but it is more general to provide only three binding posts on a coil. In this figure it will be seen that the secondary current, after leaping the gap from the central electrode of the plug to the

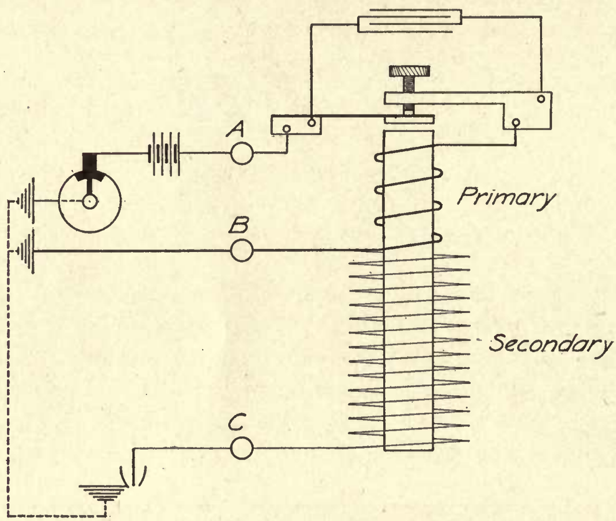


Fig. 26.

shell, returns through the metal of the engine to the grounded wire leading to the other terminal of the secondary coil. Likewise, the part of the primary circuit between the right-hand end of the primary coil and the timer is a grounded path, because the timer shaft is in metallic contact with the rest of the engine. Hence, this right-hand end of the primary coil might be grounded to any part of the engine and still have the circuit complete. Therefore, it is possible to use a single post for the ends of both primary and secondary windings and connect them to the metal of the engine by a single ground wire. This wire would serve as a part of both the primary and the secondary circuits.

Some of the most common arrangements of coils with three connections are shown in Figs. 26, 27, and 28. In these figures the primary and secondary windings have been separated at the ends of the core for the sake of clearness. Figure 26 shows the arrangement such as was suggested could be done with Fig. 18. Here the adjacent ends of the primary and secondary coils are connected and grounded with a single wire. This gives the three binding posts *A*, *B*, and *C* on the coil. *C* connects to the plug; *B* is grounded; and *A* is the primary connection going first to the battery and then the other end of the battery being connected to the timer.

When the battery is some distance from the timer, and also when there are several coils with a single battery, as on a multi-cylinder engine, it is more convenient to use the connection shown in Fig. 27. Then, one end of the battery can be connected to the post *A* and the other end grounded. The post *B* is then connected to the timer, while *C* is connected to the plug as before. It will be seen that the coil is the same in these two cases, the only change being in the location of the

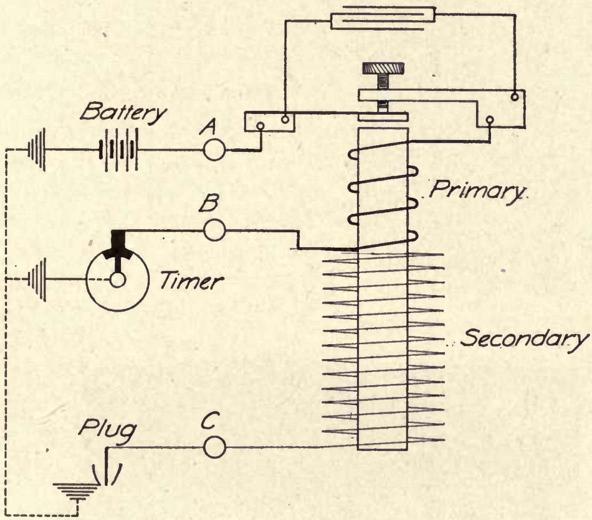


FIG. 27.

battery and timer, the grounded part of the primary circuit now being *between* the battery and the timer. This connection can also be varied by connecting the battery to *B* and the timer to *A*. In either case the secondary current, after leaping the gap in the plug, has to return to the coil through the timer or battery, but this does no harm. In some coils, the wiring has been arranged so that the vibrator is in the path of the common ground for the two coils. This is undesirable, because the spark occurs when the vibrator has broken the circuit and is open. The returning secondary current then has to jump the gap at the vibrator and this causes arcing at these points and will soon spoil them.

Figure 28 shows another arrangement in which the external connections are similar to those of Fig. 27, but the connections of the primary coil are reversed, the ground being at the end, so that the primary coil also acts as a part of the secondary coil. This slightly reduces the amount of winding by making the primary take the place of a corresponding number of turns in the secondary winding.

Figure 29 shows the external appearance of a single-cylinder box type

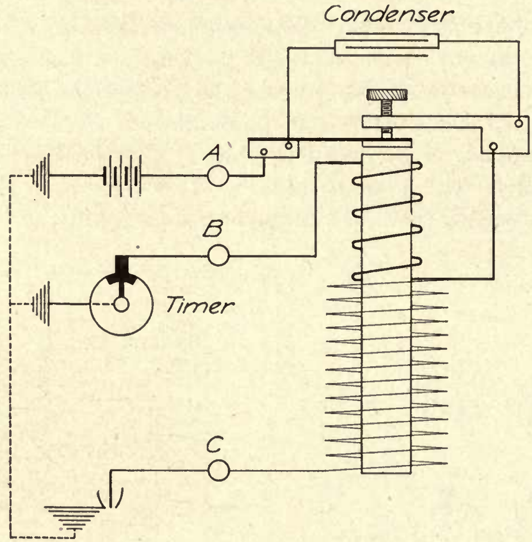


Fig. 28.

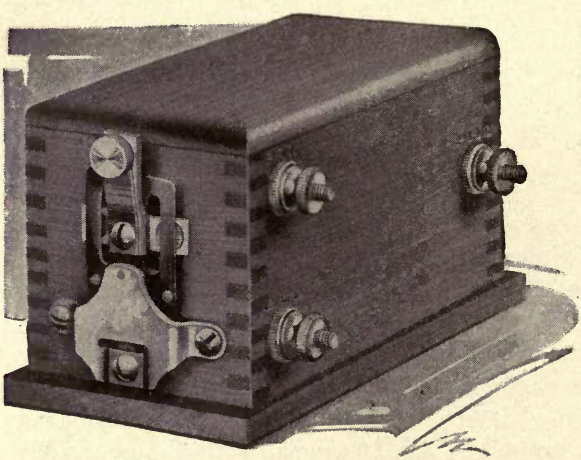


Fig. 29.—Pfanstiehl box type vibrating coil.

of vibrating coil. The terminal marked "Pri." is connected to the timer, through which the circuit is grounded. The terminal marked "Batt." is connected to one end of the battery, the other end of the battery being grounded. The current flows whenever the timer makes contact and thus completes the circuit. The terminal marked "Plug" is connected to the insulated electrode of the spark plug. The secondary current from the coil goes to the plug, leaps the gap, and returns through the common ground connection, which may be through either the battery or the timer, depending on the internal connections of the coil.

Coils of this form may also be used for two-, three-, and four-cylinder engines, the required number of coils being usually put up in a single box. When used for automobile purposes, the coils are usually exposed to view on the dash and hence are put up in compact and neat form. Figure 30 shows a four-cylinder dash coil, fitted with interchangeable slip-type units. The connections for these coils are made by contact springs bearing on metal contact plates. This makes it possible to remove any one or more coils without disconnecting any wiring. The switch on the front of the box enables the source of the primary current to be changed from battery to magneto or *vice versa*. It may also be used for two batteries, one set being held in reserve.

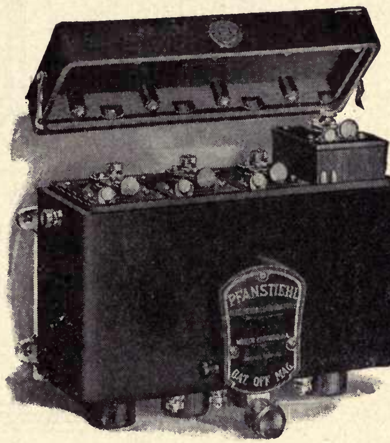


FIG. 30.—Four-cylinder dash coil.

In Fig. 31 a four-unit coil with the wiring for a four-cylinder engine is shown. The three terminals are lettered: *S*, the secondary terminal leading to the plug; *P*, the primary terminal to the timer; and *B*, the terminal connected to the batteries. The primary circuit is from the batteries, one side of which is grounded, through the coil and vibrator to the timer, where the circuit is grounded when the timer is closed, and the current returns through the metal of the engine to the batteries. The secondary circuit is from the secondary terminal to the plug, across the gap into the engine frame, and back through the timer to the coil.

Figure 32 also shows a diagram of the connections of a four-cylinder coil set with two batteries, one service set and one reserve set. The four coils are placed in a box with two terminals at the bottom. Either of these terminals is a primary terminal for the four coils, the switch on the front determining which set of cells is furnishing current to the coils. The other primary terminals at the top are connected to the four binding posts on the timer, the connections being made in the order in which the cylinders are to be fired. There are two common firing orders for four-cylinder engines, these being either in the order 1-3-4-2 or 1-2-4-3. In Fig. 32 the timer roller and arm turn in a clockwise direction and the firing order is 1-2-4-3, the coil at the extreme right being that for cylinder No. 1. In the position shown, the contact is being made for firing cylinder No. 3. In the diagram of Fig. 31 the firing order is 1-3-4-2, as indicated by the numerals on the timer, coils, and cylinders.

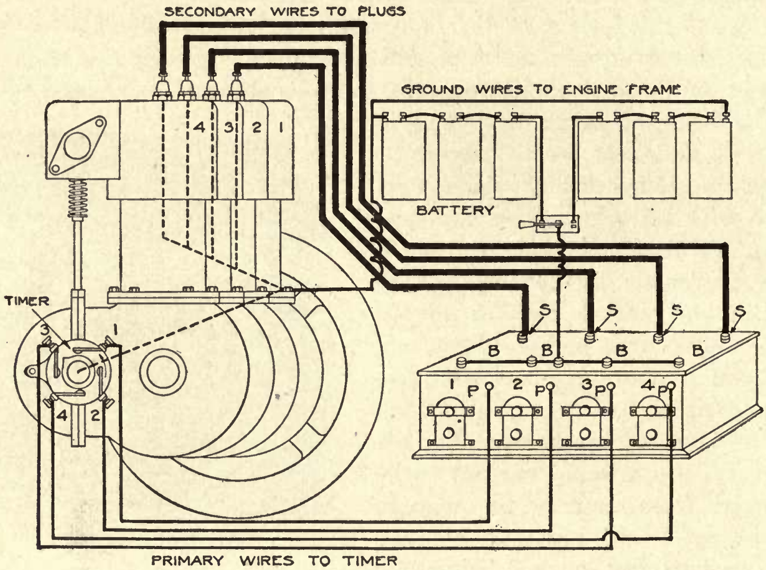
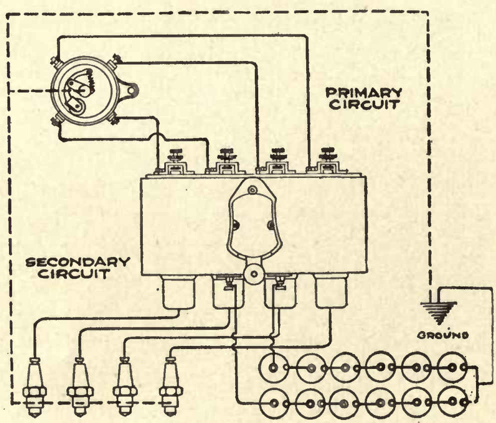


Fig. 31.—Wiring diagram for four-cylinder engine.



WIRING DIAGRAM FOR 4- CYLINDER ENGINE USING DRY CELLS

Fig. 32.

A single coil could be made to serve several cylinders by having a distributor or commutator to distribute the secondary current in succession to the different plugs. The primary timer would then act as many times as there were sparks wanted in all cylinders, closing the primary circuit after the secondary distributor had made connection for any plug. This arrangement is used quite commonly for the non-vibrating coils, as will be seen in the next chapter, but is not used to any extent with vibrating coils.

24. Master Vibrators.—A master vibrator is a single vibrator or interrupter that takes the place of the separate vibrators of the coil units on a

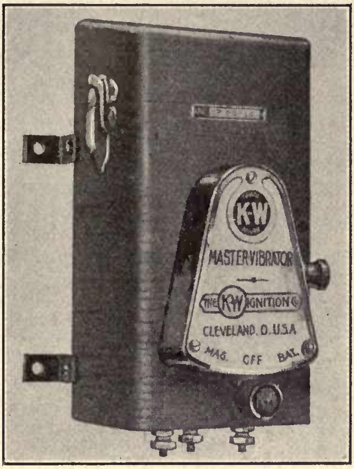


Fig. 33.

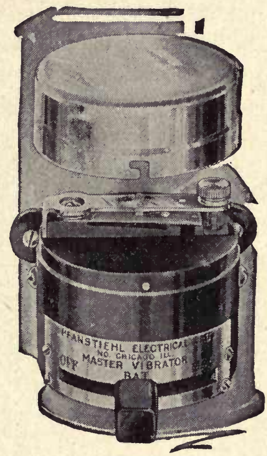


Fig. 34.—Tubular type master vibrator.

multi-cylinder engine, doing away with the separate vibrator adjustment for the different coils. With this system, one fast vibrator with a good condenser will produce sparks of like intensity at each of the plugs. Figure 33 shows the external view of a Kingston master vibrator with a three-position switch which permits the use of a magneto or battery to furnish current for ignition. A master vibrator is quite similar in construction to a vibrating coil except that it has no secondary winding. It consists of an iron core, a vibrator, across the points of which a condenser is connected, and a switch. The master vibrator is connected between the batteries and the coils so that the primary current passes through the master vibrator coil before going to the induction coils. The one vibrator thus operates regardless of which cylinder is firing. The wiring diagram shown in Fig. 36 is that for a four-cylinder coil set with a master vibrator.

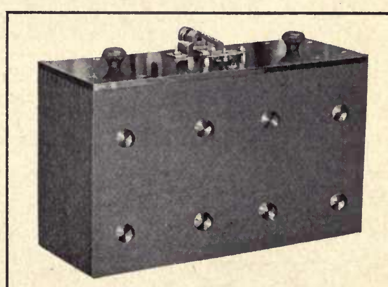


Fig. 35.—Kingston single-vibrator, four-cylinder coil.

Figure 34 shows the Pfanstiehl master vibrator, this one being cylindrical in shape. These master vibrators are built primarily for installation with coils that were built with separate vibrators, hence the separate construction.

25. Single-vibrator Multiple Coils.—Figure 35 shows a type of multiple coil for a four-cylinder engine built with a single or master vibrator. With this equipment the same results are obtained as with four vibrating coils and a master vibrator, but the master vibrator is built into this coil set instead of being a separate installation.

When a master vibrator is installed in connection with coils having separate vibrators a change is made in the coils, cutting out or short-cir-

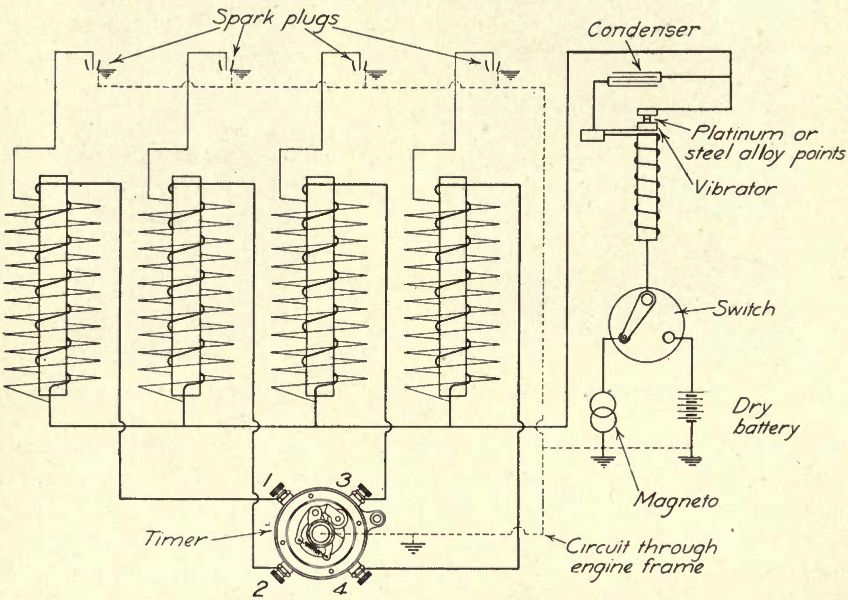


FIG. 36.—Wiring diagram for single-vibrator four-cylinder coil.

cuiting the separate condensers and vibrators. The three-position switch on the coil box is also discontinued and that on the master vibrator used instead. Figure 36 shows a wiring diagram for a single-vibrator coil. This also shows the arrangement of a coil set with which the master vibrator has been installed afterward. This diagram shows the switch thrown to magneto position so that the magneto is furnishing the primary current. The firing order is 1-2-4-3 and the connection is shown to give a spark in cylinder No. 3.

26. Installation of Master Vibrators.—Since a master vibrator is only a device for interrupting the primary current to each coil instead of having this function performed by separate vibrators, the location and method of placing it in the ignition circuit is a simple operation. On the master vibrator are three terminals marked *B* (battery), *C* (coil), and *M* (magneto) (see Fig. 37 showing the installation of a K-W master vibrator). The battery and magneto leads are removed from the main coil switch or box and attached to the master vibrator terminals. In addition to this a wire is connected from the middle post *C* of the master vibrator to either the battery or magneto terminal of the coil box. If the battery terminal is selected, the dash coil switch must be always kept in the battery position and the switch on the master vibrator used. In addition to the above changes, the vibrators of each of the separate coils must be screwed down tight to prevent them from operating and, as an extra precaution, a wire should be used to permanently connect or short-circuit the two electrodes of each vibrator as shown in the upper left-hand corner of Fig. 37. When this has been done, the wiring scheme will be similar in every respect to that shown in Fig. 36.

The demand for such a device as a master vibrator has been brought about by difficulty in securing uniform adjustments, by deterioration of the vibrator points, and by defective condensers, it being about as cheap to

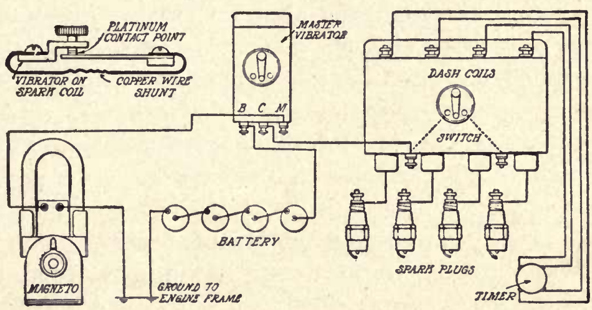


FIG. 37.—Connections for K-W master vibrator.

install a master vibrator as to replace the expensive points or buy new coils. As the condensers and vibrators of the individual coils are inoperative, any defects in those parts will not prohibit their use in the new scheme. One chief advantage is due to the fact that sparks of equal intensity are delivered to all the spark plugs by means of a single master-vibrator adjustment.

27. Coil Impregnation.—Coils are made by a special process in which an attempt is made to exclude all moisture. If any moisture remains, the coils will always cause more or less trouble, due to short-circuits and breakdowns. The usual practice consists of placing the coils in a large steam-jacketed tank, sealed absolutely air tight, and heated for 6 hours to a temperature of 250°F. This temperature, being above the boiling point of water, drives the moisture out of the windings. At the end of this period a vacuum is created in the tank, drawing out all moisture, after which a molten dielectric solution such as wax or paraffin is allowed to flow in. A pressure of 125 lb. to the square inch is maintained for 3 hours in the tank containing the coils. This pressure forces the dielectric into every pore of the paper and silk insulation, replacing the moisture that has been removed.

28. Care and Adjustment of Coils.—As moisture reduces the insulating strength of the insulation, the coils should be kept as free from moisture as possible. They require very little attention except an occasional inspection of contact points to see if they have the proper adjustment and touch each squarely. Occasionally small particles of dirt find their way between points, which cause arcing and pitting. Consequently, it becomes necessary to smooth the ragged surfaces by means of a fine flat jeweler's file or carborundum. Fine sandpaper is also very good, but emery cloth should never be used.

The adjustment of the vibrator is an important item as regards both the life of cells and wear of contact points, and the quality of spark in the spark plug. A wide gap between points permits a relatively slow vibration, and a small value of current consumption in the primary; a small gap causes a rapid vibration and allows a larger current to flow. The larger current produces a stronger magnetic field. As the voltage in the secondary coil depends upon the intensity of the magnetic field, the relative number of turns on primary and secondary coils, and the rate at which the primary circuit is interrupted, a close adjustment of the points produces a high voltage, usually high enough to leap a gap of ½ in. or more in open air.

The usual practice in adjustment of coils consists in turning the adjusting screw up until the vibrator stops buzzing, due to an open circuit; then turning the screw down slowly until the two points just touch, followed by an extra quarter turn.

Various coils require different strength of current to operate them. The average value for various coils runs from ½ amp., for light adjustment, to 2 amp. for close adjustment of vibrator points. The lighter the adjustment can be made with perfect ignition, the better it will be for the vibrator points and the batteries. Ordinarily the vibrators should give a low buzz rather than a high-pitched one.

CHAPTER III

NON-VIBRATING COILS

29. Use of Non-vibrating Coils.—Until the advent of the electric starter for automobile engines, the magneto, either low- or high-tension, was the prevailing source of current for jump-spark ignition. At the present time, since the engine is already equipped with a direct-current generator and a storage battery to supply starting current, the prevailing tendency is to use these as the source of primary current for ignition purposes and to use a single non-vibrating coil with a mechanical interrupter for the primary and with a distributor for the high-tension current. Some automobile manufacturers, however, still retain the separate magneto-ignition system. The non-vibrating coil with mechanical interrupter has also caused a revival of interest in dry cells as the source of ignition current, because of the reduction in current consumption and the increased life of the cells which can be effected with this form of ignition apparatus.

30. Non-vibrating Coil Systems.—Three combinations of current supply are found in use at present with jump-spark systems using non-vibrating coils. These are:

1. Dry cells only.
2. Direct-current starting generator and storage battery, with or without dry cells as an auxiliary source.
3. Low-tension magneto, with or without dry cells as an auxiliary source.

A few modifications of the above will be found, one of which consists in the use of a vibrating coil for starting and a non-vibrating coil for running.

Each system is made up of a source of current, a non-vibrating coil, a mechanical interrupter or circuit-breaker which is also the timer, and a condenser in the primary circuit. There is also a double-throw switch, if there are two sources of current. In the secondary circuit are the secondary winding of the coil, the distributor, and the spark plugs. The general arrangement of such a system with two sets of dry cells as the source of current is shown in Fig. 38. Either of the sets of cells may be used, according to the position of the switch on the front of the coil box. There are two main points of difference between this system and the vibrating coil system. First, there is but the one coil, and the secondary or high-tension current is led to a central revolving arm in a distributor, which directs the high-tension current to the proper spark plug. This means that the one coil must operate as frequently as sparks are desired in the different cylinders. Second, the timer and vibrator are combined into a single device which closes the primary circuit and then breaks it suddenly, so that a single wave is produced in the secondary winding of the coil. This is carried through the distributor to the proper plug, where a single spark is produced. The device for closing and then interrupting the primary circuit is variously called the timer, contact-maker, circuit-breaker, or interrupter. This device and the distributor are usually mounted together and are driven from the camshaft of the engine. In the system shown in Fig. 38, one end of the batteries is grounded. The other end is

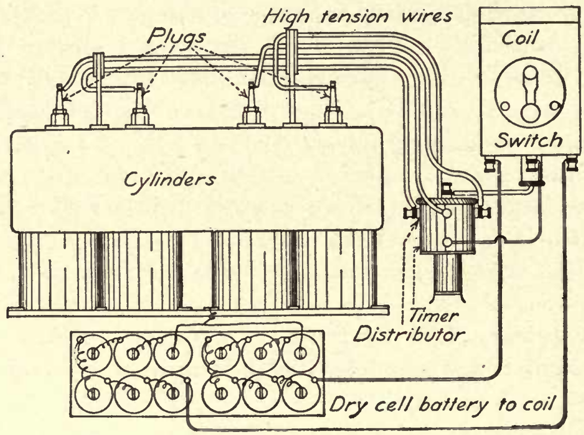


FIG. 38.—Non-vibrating coil system for four-cylinder engine.

connected to the primary winding of the coil through the switch, while the other end of the coil is connected to the timer. When the circuit is closed by the timer, this wire is connected to the ground through the timer shaft, and the primary current is thus allowed to flow and energize the coil. When the timer breaks this circuit, the condenser absorbs the induced current in the primary. The induced current in the secondary winding of the coil goes to the central pole of the distributor, then to the plug of one of the cylinders, where it leaps the gap and returns to the coil through the grounded battery, the other end of the secondary coil being connected to the switch so that the battery ground connection can form a common ground for both coils.

31. Transformer Coils.—In the study of ignition devices, the coils are classified into two groups: "kick" or single-winding coils for make-and-break systems, and jump-spark or double-winding coils for jump-spark systems.. As the term *transformer coil* is sometimes used, the question may be raised as to what relation the construction of the latter bears to other electrical transformers. In general, but two types of transformers are made: *closed-core,* and *open-core.* The former is used for conversion of voltage in electric light and power mains, and has a primary and a secondary winding, the one usually containing ten or twenty times as many turns of wire as the other.

Transformers that are built with an open core are better known commercially as induction coils, to which class belong the jump-spark ignition coils, telephone induction coils, induction coils for use in wireless telegraphy, etc.

The difference between these types of coils in the function they have to perform makes a difference in construction necessary. In lighting transformers, the primary of the coil receives alternating current from an alternating-current generator, and there is induced in the secondary winding an alternating current of higher or lower voltage, depending on whether it is a step-up or step-down transformer. Figure 39 shows a type of

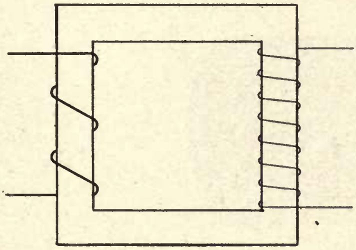


FIG. 39.—Closed-core transformer.

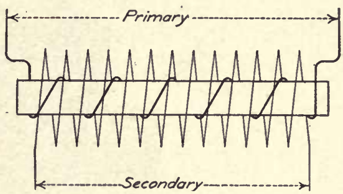


FIG. 40.—Open-core induction coil.

small transformer used for doorbell work, the 110-volt lighting current being stepped down to 4 volts, which low-voltage current is used to operate the bell in place of current from dry cells. Alternating current usually reverses its direction of flow in lighting circuits 120 times per second and, as two reversals constitute what is called a cycle, the lighting current is said to have a frequency of 60 cycles per second.

In the case of telephone induction coils, Fig. 40, the current in the primary winding is direct, that is, it flows always in the same direction, but it is varied in intensity according to the sounds beating upon the diaphragm of the transmitter. It is estimated that the frequency of the human voice is somewhere between 800 and 1200 variations per second. Consequently, it is a direct current of rapidly varying intensity flowing in the primary winding which induces the current in the secondary winding.

In ignition coils, the interruption of the current flowing in the primary winding causes a current to be induced in the secondary winding. This interruption is accomplished electrically in a vibrating coil by means of a vibrator, or in a non-vibrating coil by a mechanical interrupter.

Thus, we see that an alternating current can be induced in the secondary coil of a transformer or induction coil by passing through the primary coil any of the following: (*a*) an alternating current; (*b*) a direct current of varying strength; (*c*) an interrupted current.

32. Coil Construction.—The essential parts of a non-vibrating ignition coil are: a soft iron core, a primary winding of coarse insulated copper wire, and a secondary winding of fine insulated copper wire. In some coils a condenser is included, or the condenser may be placed with the circuit-breaker. The core is made up of a round bundle of fine soft iron wires, usually enveloped by a paper tube. On this is wound usually two layers of No. 16 or 18 gage insulated copper wire to form the primary.

Some thin insulating material of high dielectric strength, such as empire cloth, is then wrapped on the primary winding, after which the secondary winding is then put on either in layers extending the length of the coil or in pancakes. The construction and insulating process is quite similar to that described for vibrating coils in Chapter II, except that there is no vibrator.

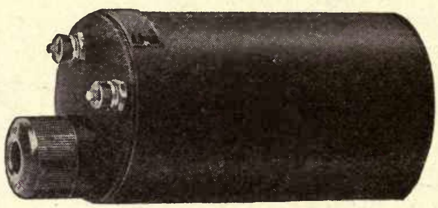


FIG. 41.—Non-vibrating coil.

The majority of coils are made cylindrical or tubular. If the condenser is included, it is well insulated from the secondary winding and is so located that it will be impossible for the current to jump from the coil to the condenser plates. Figure 41 shows a tubular non-vibrating coil having one secondary terminal, one primary terminal, and one terminal common to both. When used on automobiles, it is mounted under the hood or at the back of the dashboard. It is made both heatproof and waterproof. There are also a number of coils made which are encased in boxes and provided with switches.

33. Action of Coil.—The action of a non-vibrating coil differs from that of a vibrating coil in only one respect, the method of interrupting the flow of current through the primary. Figure 42 shows the wiring diagram of an ignition circuit for a single-cylinder engine. The primary circuit is made up of the primary winding, the condenser, the battery, and the circuit-breaker. The secondary circuit contains the secondary winding and the spark gap. This diagram shows the coils separated, although in reality they are both wound about the core, which is not shown here. The iron core is common to both. Since one terminal or electrode of the spark plug is in contact with the engine, in other words *grounded*, it is necessary to have the other end of the secondary winding grounded as shown. In coils of this style, the terminals are always marked to enable the operator to make the proper connections. The high-tension terminal can never be mistaken, because it consists of a conductor with thick rubber insulation, whereas the other terminals have thin insulation.

The operation of the coil is as follows: When the primary circuit is completed in the circuit-breaker, the iron core becomes magnetized. It requires an appreciable amount of time for the current to rise to full value, usually from 0.02 to 0.1 second, depending upon the construction of and material in the coil and core. The circuit is then opened suddenly in the circuit-breaker, and the magnetic field dies out quickly. This dying field induces a high voltage in the secondary coil. The faster the field dies out, the greater will be the voltage in the secondary coil.

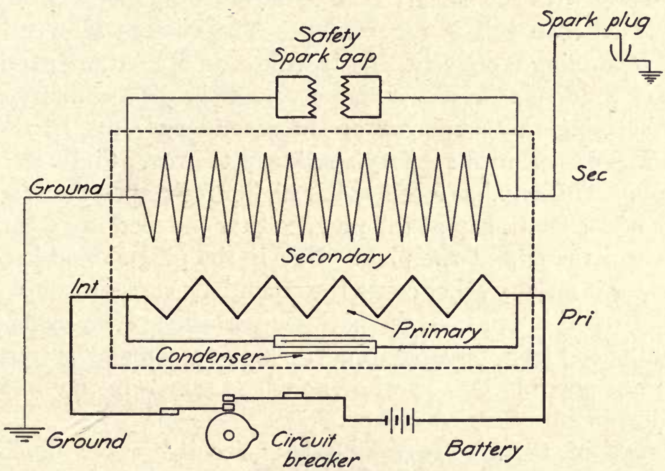


FIG. 42.—Wiring diagram for non-vibrating coil with single-cylinder engine.

Owing to the fact that current tends to flow in the primary coil for a short period after the contacts open, and in the same direction as the current from the battery, the magnetism of the core can not die out quickly unless a condenser is provided. This action is the same as that in a vibrator coil. A condenser composed of alternate layers of tinfoil and waxed paper or mica is bridged across the terminals of the primary winding, either in the coil or at the two contacts in the circuit-breaker. When the contacts start to separate, the primary current tends to keep flowing across the gap, due to what is known as self-induction. If there were no condenser, a large arc would be formed and the points would soon burn away. In addition to this, there would be only a low voltage induced in the secondary winding, possibly strong enough to jump a gap of about $\frac{1}{32}$ in. in open air. When the condenser is used, its plates absorb the primary current and prevent the formation of an arc. A deeper study of the action of a condenser reveals the fact that this charge received by the condenser immediately surges back into the primary winding and, by flowing in the opposite direction to the original current, assists in the rapid destruction of the magnetism of the core. This greatly increases the voltage induced in the secondary winding. The current then surges back again into the condenser, which becomes charged again, but not so highly. The current thus oscillates for a short period and induces in the secondary coil a rapidly alternating high voltage which produces a short shower of sparks, which appears to the eye, however, as a single spark.

A good jump-spark coil is expected to furnish at the secondary terminals a hot spark about 1/4 in. long in the open air. This is necessary in order to ensure a spark 1/32 in. long at the spark plug gap in the presence of gas under pressure, since the resistance of the gas to the passage of the spark increases with the density or amount of compression of the gas. A higher voltage than this is superfluous. The voltage of a coil may be increased by adding more cells, but it will mean a greater current flow in the primary winding as well as a higher voltage in the secondary, and may result in harming the condenser or the secondary coil. In the system shown in Fig. 42 is shown a safety spark gap to prevent injury to the secondary coil. This gap has a somewhat higher resistance than the normal resistance of the spark gap at the plug, so that the secondary current will normally leap the gap at the plug. But if the plug should become disconnected, or if for any other cause the secondary current would not have this regular path, it can take the path through this safety spark gap and thus save the coil from possible injury. If the secondary current had no path it might possibly be powerful enough to puncture the insulation of the winding in its effort to escape.

34. Types of Circuit-breakers.—The circuit-breaker illustrated in Fig. 43 is that used on the Remy low-tension magneto with non-vibrating coil. In this case the magneto supplies the low-tension current for the primary winding of the coil. The circuit-breaker is built onto the magneto, and the double-lobed cam shown in the center of this figure revolves with the magneto shaft. The housing of the circuit-breaker is stationary except as it is shifted by the arm at the right to change the time of the spark. This same breaker is also used to interrupt the battery current used for starting. A study of this breaker shows that the circuit is closed when the low places on the cam are in contact with the breaker arm, and is opened as the high places come into contact. For a four-cylinder engine this cam revolves at crankshaft speed, thus producing four sparks in two revolutions. On a six-cylinder engine it would revolve at one and one-half times crankshaft speed. An examination of the shape of the cam will show that the breaker points are in contact for a comparatively long interval, approximately one-half of the time between sparks. This construction is quite necessary when a magneto is used as a source of current, because it requires a considerable time for the current to build up in the armature and coil. (The theory of the magneto is treated in Chapter V.) It can be readily seen that if dry cells are used continuously with such a breaker, the length of their life would be comparatively short, due to the drain of current during this long contact. For example, on a certain automobile equipped with a low-tension magneto and five dry

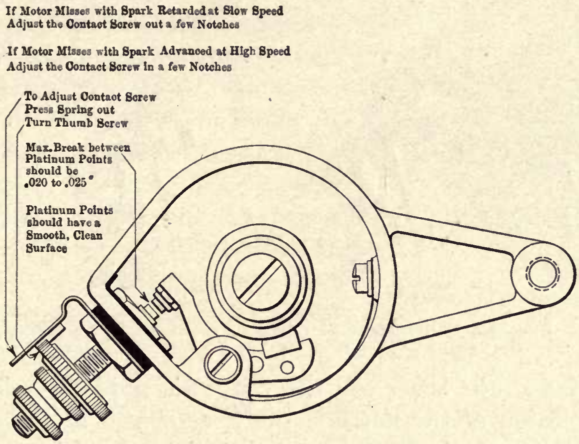


FIG. 43.—Circuit-breaker of Remy magneto.

cells, the cells lasted for 6 months when used only for starting, but when used steadily in place of the magneto they were exhausted in a week. This applies in general to all magneto circuit-breakers and not especially to the one shown here.

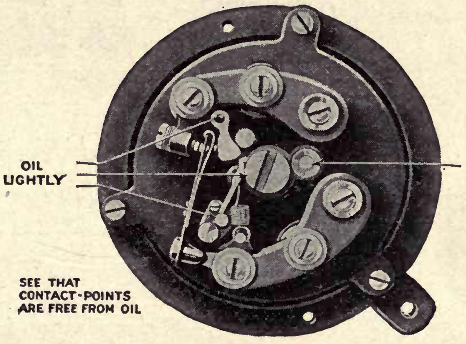


FIG. 44.—Atwater-Kent contact-maker.

A type of circuit-breaker constructed on the principle of a rapid make-and-break and therefore especially suitable for battery ignition is shown in Fig. 44. This is the breaker mechanism or *contact-maker,* as it is called, of the Atwater-Kent system. The time of contact and the speed of the break are both independent of the speed of the engine and the contact can be adjusted to secure the best possible action in the coil. The closing and opening of the points are accomplished so quickly that the eye can not follow the movements. Figure 45 shows the operation of the contact-maker. The notched shaft is gear-driven from the camshaft of the engine and has one notch for each cylinder. In a four-stroke engine this shaft revolves at one-half crankshaft speed. The first view shows the steel lifter being pulled forward by the notched shaft. When pulled

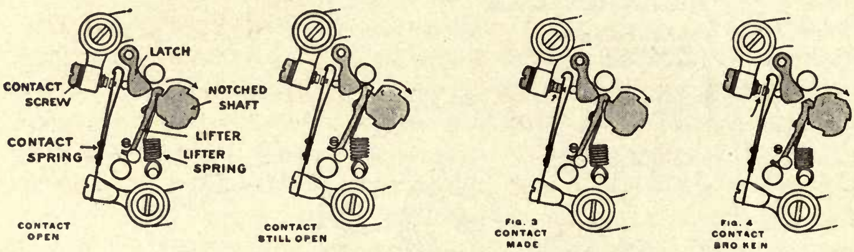


FIG. 45.—Operation of Atwater-Kent contact-maker.

forward as far as the shaft will carry it, it is suddenly released by the further revolution of the notched shaft, as shown in the second view. The spring then pulls the lifter back to its original position. In returning it strikes the latch, thus closing the circuit at the contacts, as shown in the third view. The contact is immediately broken by the contact spring

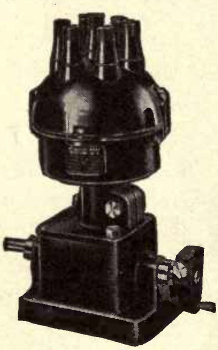


FIG. 46.—Exterior of Atwater-Kent unisparker.

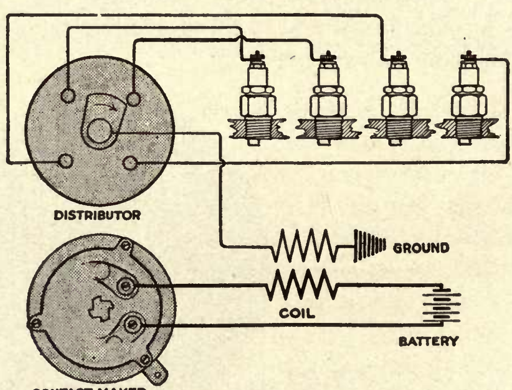


FIG. 47.—Wiring diagram for Atwater-Kent system.

as soon as the lifter has drawn back to its original position, as shown in the fourth view, where it is now ready to be pulled forward by the next notch.

The contact points are adjustable. All other parts are of glass-hard steel. This unisparker operates in conjunction with a non-vibrating coil and a distributor. The distributor is mounted in a unit with the contact-maker, its shaft engaging with the slot in the shaft shown in Fig. 44.

This unit is called the *unisparker* and is shown in Fig. 46. The wiring diagram is shown in Fig. 47.

Two important characteristics of this device are the duration of current flow and the rate of contact operation. It is impossible for the engine to stop in any position which would leave the circuit closed in the contact-maker. In some interrupters it is possible for the engine to stop in such a position that the circuit would be closed, provided the attendant forgot to open the switch. The other feature, the spring-operated contact and break, makes it possible to secure the same quality of spark at the plug whether the engine is operating fast or slow. Owing to the economy in battery consumption, dry batteries may be economically used for current supply if desired.

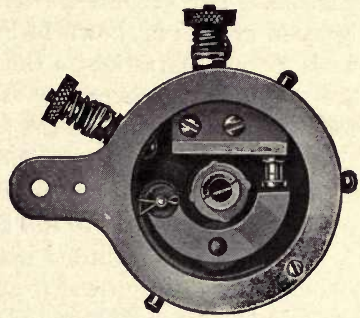


FIG. 48.—Connecticut interrupter.

Figure 48 shows the Connecticut interrupter, as they call it, designed

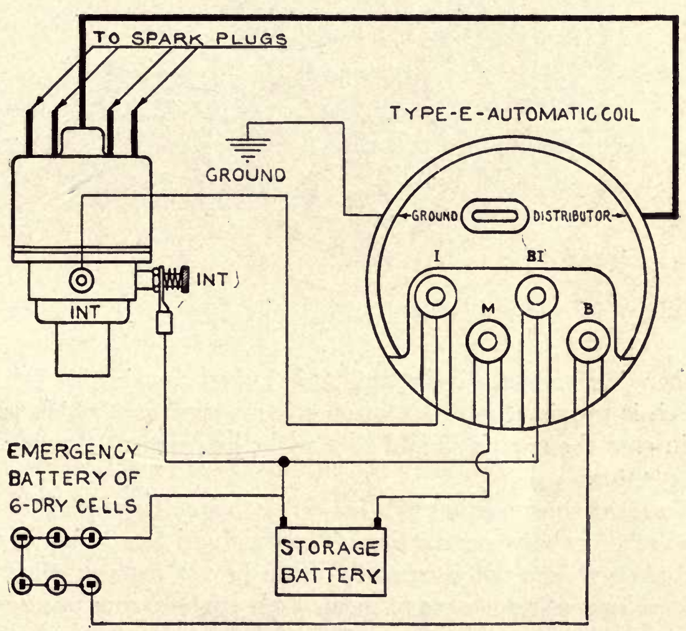


FIG. 49.—Wiring diagram for Connecticut type E ignition system.

for use with storage battery current, with dry cells for emergency use. The central revolving shaft or cam is provided with as many projections or lobes as there are cylinders on the engine. The breaker arm is provided with a single insulating roller, bearing on the cam. This breaker arm is well insulated from the frame of the mechanism, as is also the stationary contact. The device is extremely simple in construction.

The mounting of the distributor on top of the interrupter is shown in Fig. 52. The general wiring arrangement of the Connecticut Type E ignition system is shown in Fig. 49. This is intended primarily for use with storage batteries as the source of current, although dry batteries are provided for emergency use. One side of both batteries is connected to the interrupter and to the terminal marked *BI* on the coil. The other side of the storage battery is connected to the *M* terminal, while the dry battery is connected to the *B* terminal. The other terminal of the interrupter is connected to the *I* terminal of the coil.

The switch is mounted with the coil. Pressing the *M* button on the switch causes the current from the storage battery to be used. Pressing the *B* button connects the coil with the dry battery and uses that current. One end of the secondary coil is grounded and the other end connected to the central post of the distributor.

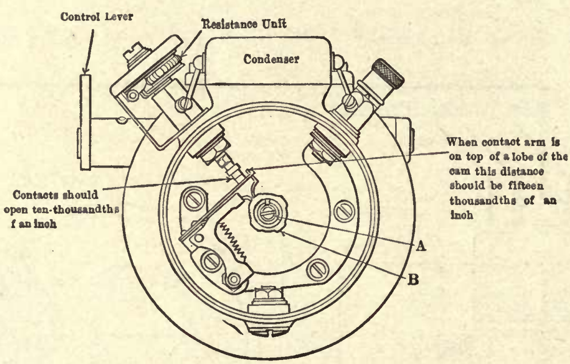


FIG. 50.—The Delco timer.

As there is a comparatively long period of contact in this interrupter, the switch is provided with an automatic arrangement which opens the circuit in case the engine should stop with the primary circuit closed at the interrupter.

The current consumption of a non-vibrating coil system is dependent upon the relation between the time of contact and the design of the coil. A short contact does not necessarily mean lowest battery consumption, nor does a long contact always mean high current consumption. The winding and core of a coil to operate with long contact may be designed to build up slowly, so that the full magnetism and full current flow are reached just before the break in the circuit occurs. The coil which operates with a short period of contact must build up rapidly.

Figure 50 shows the circuit-breaker or timer of the Delco system.

This uses storage battery current or current from the starting generator, with a dry battery as a reserve source. In this device the condenser is incorporated in the timer. The timing of the ignition may be adjusted by loosening the central screw *A* and shifting the cam.

The *Resistance Unit* in Fig. 50 is a coil of resistance wire, wound on a porcelain spool, mounted on the timer housing. Under ordinary conditions the wire remains cool and offers little resistance to the passage of current. However, if for any reason the primary circuit should remain closed for any considerable length of time, the passage of current through the coil would heat it, thus increasing its resistance to a point where very little current could pass, and insuring against waste of current from the battery and damage to the induction coil and timer contacts.

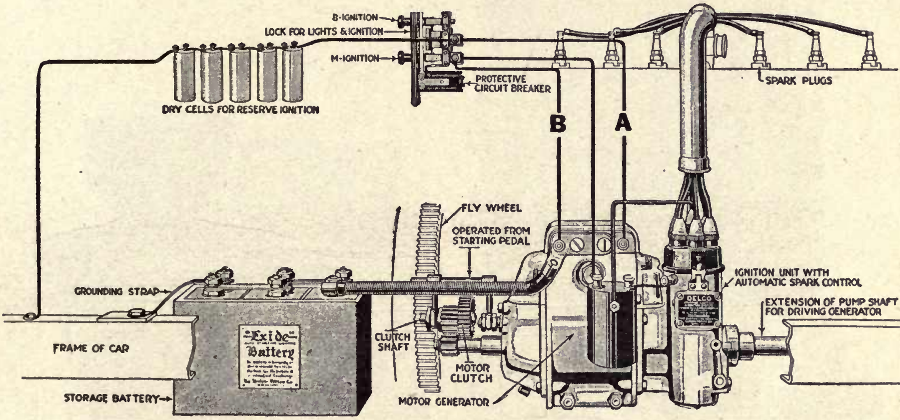


Fig. 51.—The Delco ignition system.

Figure 51 shows a Delco ignition system complete. At the left are seen the storage battery and the dry battery, each with one terminal grounded to the frame of the car. In the right foreground is the motor-generator which supplies current to the storage battery when the engine is running. It is also used as a starting motor, taking current from the storage battery. On this generator are mounted the coil and the timer and distributor. The storage battery is connected to the motor-generator and thence to the ignition switch by the wire *B*. If the *M* button on the switch is pulled the storage battery current is used for ignition. If the *B* button is pulled the dry battery current is used. In either case, the current goes from the switch to the primary winding of the coil. The other end of the primary winding is connected to the timer, where the circuit is completed at the proper time. The high-tension current from the secondary winding of the coil is led to the center of the distributor and is there directed to the plugs on the engine.

35. Distributors.—The high-tension induced current from the secondary winding of the coil is directed to the spark plugs in proper order by the distributor. There are many different forms of distributors, but they all have a central arm which receives the high-tension current from the coil. This arm revolves and makes contact in succession with metal segments connected to the different spark plugs. In a four-stroke engine, the distributor arm revolves once for each two revolutions of the crankshaft. The distributor cap, in which are mounted the metal segments, is usually made of a high-grade insulating material such as hard rubber or bakelite.

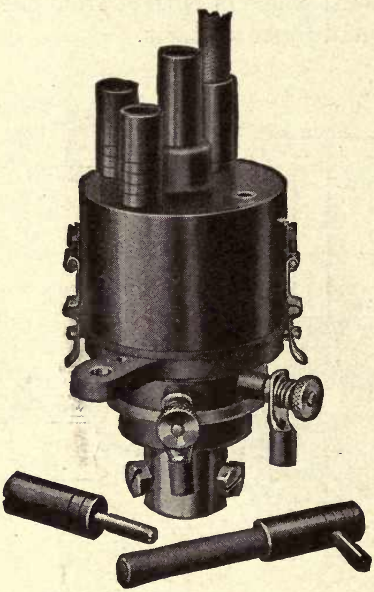


Fig. 52.—Connecticut combined interrupter and distributor.

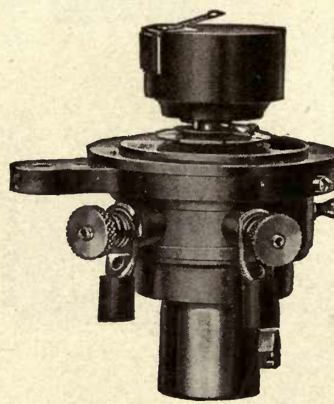


Fig. 53.—Connecticut distributor with cap removed.

Figure 52 shows the Connecticut distributor mounted above the interrupter. The central projection at the top is for the high-tension connection from the coil. Those spaced around it are for the connections to the plugs. In Fig. 53 is shown the revolving part of the distributor, the cap having been removed. This view shows the spring contact for receiving the current from the central connection, and the carbon brush projecting from the side to distribute the current to the different contact segments. The distributor always makes contact before the spark is produced by the interruption of the primary current at the circuit-breaker, and maintains contact until after the sparking current has ceased flowing. This is necessary to protect the coil and to prevent the distributor contacts from being burned.

In the Connecticut and Atwater Kent ignition systems, which have been illustrated, the distributor and circuit-breaker are mounted as a single unit. The spark advance and retard are obtained by swinging the entire mechanism about its axis, just as is done with the timer in vibrating coil ignition systems.

In Fig. 54 is shown the Westinghouse interrupter and distributor with the caps removed. This is for a six-cylinder engine, as can be seen

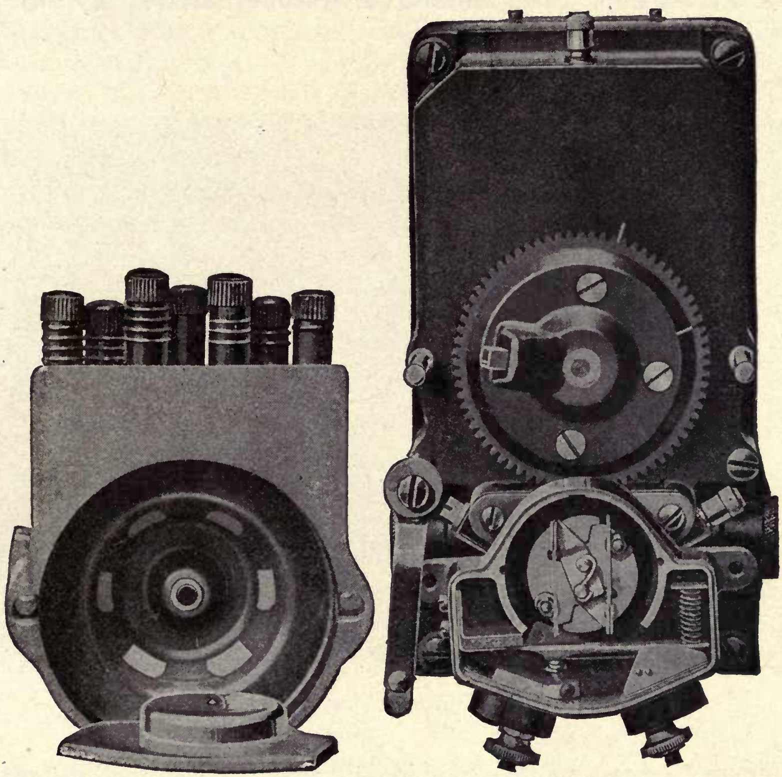


Fig. 54.—Westinghouse distributor and interrupter cover removed. Position of centrifugal weights with engine idle.

from the six contact segments inside the distributor cover. The interrupter makes two contacts and breaks in each revolution and hence must turn three times as fast as the distributor. The central arm of the distributor is gear-driven from the interrupter shaft.

Where magnetos are used as the source of current, the circuit-breakers and distributors are usually built as part of the magnetos. The coil and switch are then usually mounted on the dash. When automobiles are equipped with electric starting and lighting systems and use this current for ignition, the circuit-breaker and distributor may be mounted as a part of the electric generator as was shown in Fig. 51.

High-tension circuits differ from low-tension circuits in two respects: they do not require perfect electrical contacts, whereas low-tension circuits do, and they require a much higher grade of insulating material. Some distributors have small carbon brushes to form contact between the revolving arm and the conductors leading to the spark plugs. In others there is a small gap of a few thousandths of an inch across which the current must leap. This form of construction obviates any wear due to sliding contacts.

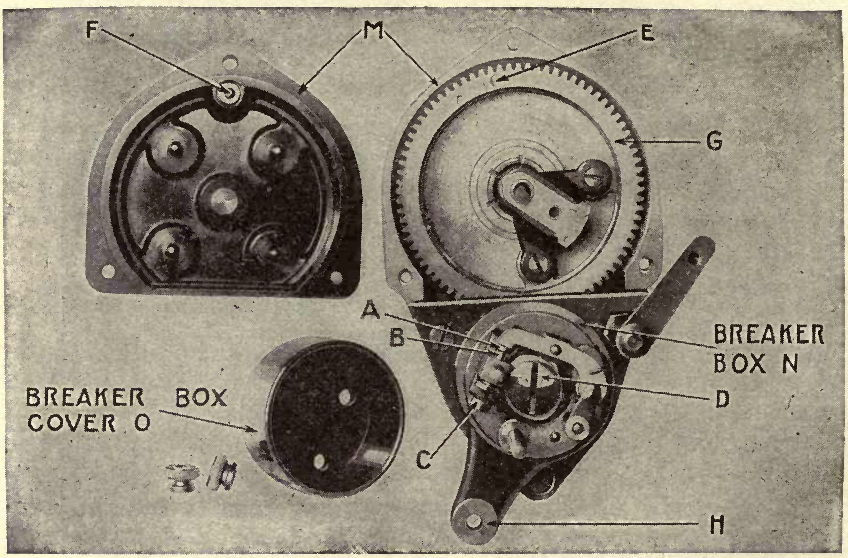


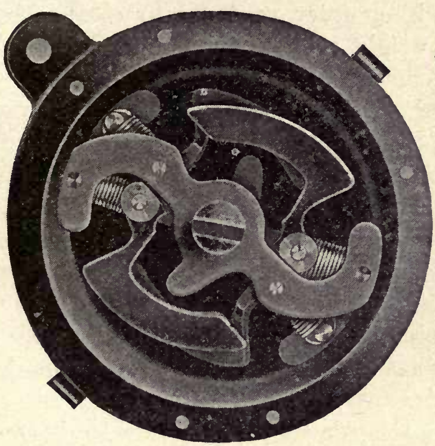
FIG. 55.—Remy distributor and breaker box, disassembled.

Figure 55 shows another combination circuit-breaker and distributor for storage-battery ignition systems. This is made by the Remy Electric Co. The distributor cap is made of bakelite or some similar heat-resisting insulating material which possesses high dielectric strength. The arm is fitted with a carbon brush that makes contact with the imbedded metal segments. The segments are long to take care of the advance and retard of the spark without making it necessary to shift the distributor when the spark time is changed, which is done by swinging the circuit-breaker housing.

It is a well-known fact that it requires a special grade of insulation to confine a high-tension current to the conductor carrying it. If special insulation were not provided on these conductors, the current might jump to the framework of the engine without passing through the gap in the spark plug.

36. The Safety Spark Gap.—In order to protect the windings of a spark coil from a breakdown due to a high voltage, a safety spark gap is included in the construction of most non-vibrating coils. This consists merely of two pieces of metal with saw-toothed edges about ½ in. apart mounted in an accessible location. If the high-tension wire to a spark plug becomes disconnected, the current will leap across the safety-gap points and thereby protect the coil from a breakdown. Occasionally the gap in a spark plug widens accidentally, in which case the spark may appear in the safety gap. It may be safely said that whenever a spark occurs in the safety gap there is trouble in the spark plugs or in the conductors leading to them. A safety spark gap is shown in the diagram of Fig. 42.

37. Automatic Spark Advance.—Some engines are equipped with a fixed timing device that causes ignition always at the same piston position



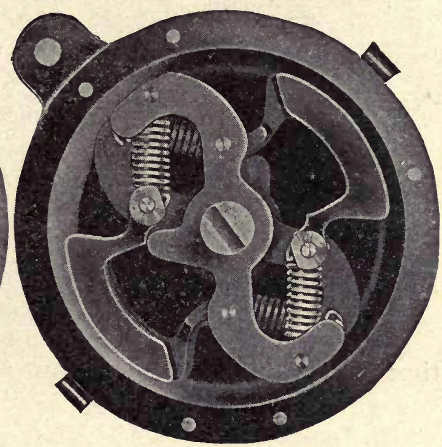


FIG. 56.—Low-speed position. FIG. 57.—High-speed position.
Atwater-Kent automatic spark control.

no matter at what speed the engine is running. In order for the engine to be efficient at normal running speed, the spark must be advanced so that it will occur before the piston reaches upper dead center on the compression stroke. This is due to the fact that it requires an appreciable time for the flame to spread and complete the combustion of all the gas. The spark setting should be enough in advance of upper dead center to allow the exploded mixture to produce its maximum pressure just as the piston starts on the working stroke.

Standard practice provides for a means of retarding of the spark for starting and for advance as the engine speeds up. In automobile practice, the amount of advance is ordinarily left to the discretion of the operator, except in a number of systems now on the market in which the variation of spark-setting is accomplished automatically as the speed of the engine changes.

Figure 56 shows the centrifugal governor which advances the spark time as the speed increases, on the Atwater-Kent system. The rotating shaft is divided at the governor and the circuit-breaker placed above it. As the governor weights expand, they rotate the upper part of the shaft in its own direction of rotation, thereby shifting the notched shaft of Fig. 45 and making and breaking contact earlier than at low speed. Any slight change in speed changes the spark advance just the proper amount, so that the spark is always exactly timed. Figure 57 shows the governor at high speed.

Another form of automatic spark advance is shown in Figs. 58 and 54. The operation of this system begins with the closing of the primary circuit of the coil when the centrifugal weights push down the fiber bumper, allowing the interrupter contacts to close. As the weight moves off the fiber bumper, the contacts suddenly separate. As the speed of engine increases, the weights are thrown out from the center and automatically advance the time of closing or opening the interrupter contacts. At the same time, due to their shape, they keep the contacts closed during a greater portion of the revolution when running at high speed. This makes the time of contact practically the same at all speeds and prevents the spark voltage from falling off at high speeds.

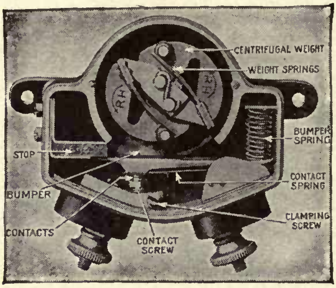


Fig. 58.—Westinghouse interrupter. High-speed position.

38. Ignition Relay.—The ignition relay is an ingenious device incorporated in some of the Delco ignition circuits, the function of which is to conserve the energy of the dry cells. When the dry cells are used as a main source of ignition, the relay causes a single spark at each plug; but for starting purposes, the relay acts as a master vibrator, producing a shower of sparks at each plug. This relay consists of an iron core, one coarse and one fine insulated winding, a condenser, and a pair of vibrator contacts. The wiring diagram is shown in Fig. 59.

The timer contains two breakers, one for dry battery and one for storage battery. When the *S* button of the switch is operated, the high resistance winding of the ignition relay is cut out of the circuit. Then when contact is established in the timer, a current will flow through the primary of the coil and the low-resistance winding of the relay. The ignition relay vibrates, causing an intermittent current in the primary and thereby inducing a shower of sparks in the secondary circuit.

When the *B* button is depressed, the *S* button automatically returns to normal position. Then, when contact is established in the timer, current will flow as before described and will break the circuit at the relay vibrator. But now the armature of the relay is held to the core and the points are not permitted to reëstablish contact, because enough current still flows through the high-resistance winding to hold the armature. As soon as the contact is broken in the timer, the ignition relay

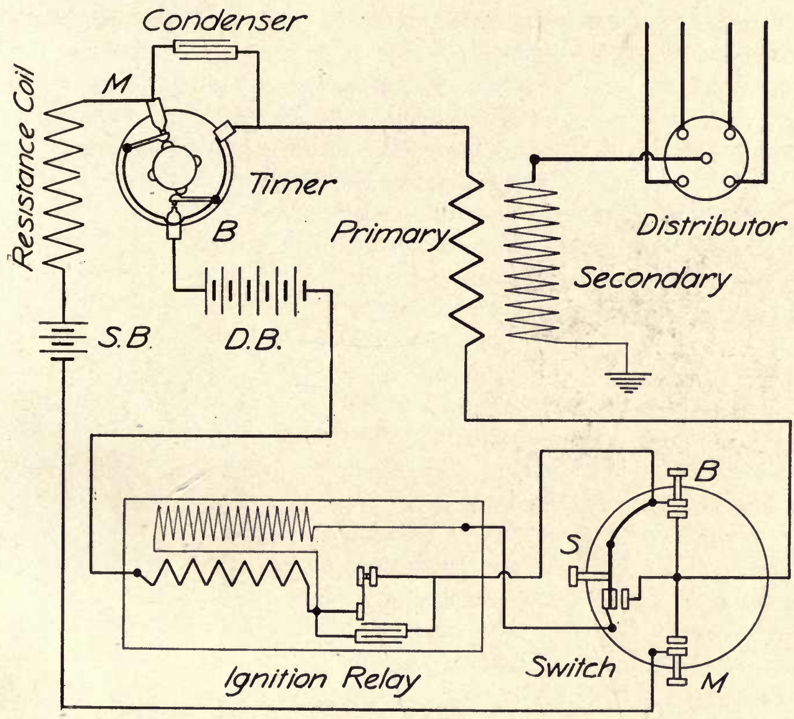


Fig. 59.—Diagram of Delco system with ignition relay.

returns to normal condition. The high-tension current is induced in the secondary of the induction coil at the time the points are separated in the relay.

The *M* button, when depressed, connects the storage battery to the ignition system, the relay now being inoperative. As will be seen by a study of the diagram, the current is induced in the secondary of the non-vibrating coil at the time the contact in the timer is broken. It will thus be seen that depressing the *M* button gives a single spark, using current from the storage battery or generator. Depressing the *B* button gives a single spark, using current from the dry battery. Depressing the *S* button gives a shower of sparks, using current from the dry battery.

In order to get the same time of firing, two separate contacts are used for storage and dry batteries. The storage battery contacts break at the same instant that the dry battery points make contact, because the one gives the spark at the "break" while the other gives the spark at the "make."

CHAPTER IV

BATTERIES

39. Kinds of Cells.—A battery is made up of a number of units called cells. A cell is defined as a source of electrical pressure made up of two dissimilar elements immersed in a solution called the *electrolyte,* which is capable of acting more intensely on one of the elements than on the other.

A simple cell made up of elements of carbon and zinc in a solution of sal ammoniac is shown in Fig. 60. When the terminals of the cell are connected so as to complete a circuit, a chemical action takes place within the cell, which results in a flow of electricity from the zinc element to the carbon element within the cell and from the carbon element, through the external circuit, to the zinc element. All cells are grouped into two classes, *primary* and *secondary.*

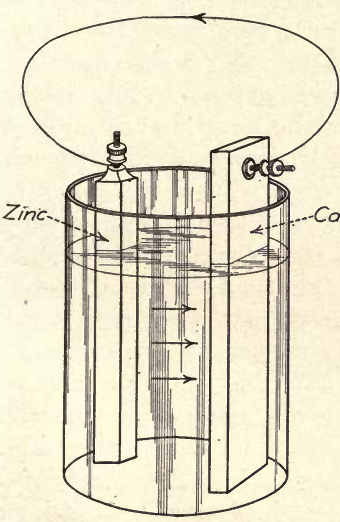


Fig. 60.—Wet primary cell.

A primary cell is one in which the electrical energy is produced by a chemical action which destroys one of the elements. A dry cell is a primary cell. When a primary cell has become exhausted it can be replenished only by replacing the elements or the electrolyte.

A secondary or storage cell must first be charged by sending a direct current through it, thereby causing the elements to undergo a chemical change. Then, when the cell is used as a source of current, the reverse chemical change takes place, restoring the elements to their original composition. Consequently, a cell of this type can be used repeatedly by providing means of recharging it when it becomes exhausted or discharged.

40. Primary Cells.—The service demanded of primary cells by ignition systems is such that only certain cells are suitable. In the type of cell shown in Fig. 60 a continuous flow of current quickly produces *polarization.* The chemical action that takes place during a constant flow of current from this cell causes a coating of hydrogen bubbles to appear on the carbon element. This layer shuts off the electrolyte from the carbon element and prevents the chemical action. This is known as *polarization.* After the circuit is opened, the hydrogen will disappear more or less rapidly and the cell is then restored to its normal condition. The flow of current for ignition devices is intermittent, but the intervals of rest are very short and the cells are usually called upon for continuous service for several hours at a time. Consequently some provision must be made in the chemical construction of the cells to prevent polarization or to cause very rapid recuperation. Cells in which polarization occurs are sometimes called *open-circuit* cells, while those in which polarization does not occur are called *closed-circuit* cells.

41. Wet Cells.—Wet cells are seldom used at present for ignition purposes because of the space which they occupy and the danger of the containers being broken. One cell quite suitable for this service is the Edison primary cell. This cell contains a positive element of copper oxide, a negative element of zinc, and a solution of caustic soda for the electrolyte. After the cell is assembled and the electrolyte poured in, a ½-in. layer of paraffin oil is added. This floats on the top and prevents corrosion and protects the solution from the air. In this cell, the hydrogen which is freed by the chemical action of the cell combines with the oxygen in the plate of copper oxide, thus forming water. In this manner polarization is prevented. This cell gives about 0.7 volt, but can furnish a steady current of several amperes. The life of one of these cells depends upon the size of the elements.

It will be remembered that the *volt* is the unit of electrical pressure like the pressure in a water pipe. The *ampere* refers to the electrical unit for the rate of flow of current. It corresponds in a water pipe to the rate of flow of water through the pipe in such terms as gallons per second or cubic feet per minute. A cell will give a certain voltage, while the rate of flow of the current will depend on the resistance of the circuit. The ability of a cell to maintain a certain flow will depend on the size of the elements and the provision against polarization.

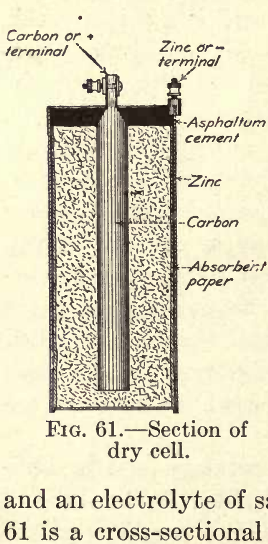


FIG. 61.—Section of dry cell.

42. Dry Cells.—By far the most common type of primary cell is the dry cell. It is made up of a zinc container lined with a good grade of blotting paper; a carbon positive element; and an electrolyte of sal ammoniac, zinc oxide, and zinc chloride. Figure 61 is a cross-sectional view of a dry cell. The space between the carbon rod and the zinc cup is filled with powdered carbon saturated with a solution of the above-named chemicals. The proportions of chemicals used are manufacturers' secrets. There is included also another chemical known as manganese dioxide. This substance, rich in oxygen, acts as a depolarizer. If the cell discharges slowly, the hydrogen is united with the oxygen as rapidly as released, forming water, as before mentioned. However, when the discharge rate is large the hydrogen is released too rapidly to be taken up by the oxygen, in which case the cell will polarize. If the cell is allowed to stand long enough for the hydrogen to be absorbed, it will regain its normal condition.

Not all dry cells are suitable for ignition. Cells which may be suitable for intermittent use on doorbells, annunciators, telephones, etc., may have a rather high internal resistance. By *resistance* is meant the opposition offered to a flow of current. Ignition cells should be constructed so as to have a low internal resistance. In addition to this, a special effort is made to reduce polarization to a minimum.

43. Testing Cells.—The voltage of a cell depends entirely upon the kind of elements, the composition of the electrolyte, and on the temperature. With identical materials, a very small cell will show the same voltage as a very large one. On the other hand, the amperage or capacity of a cell depends upon its size. If the terminals of a voltmeter are connected directly to a new dry cell a reading of about 1.4 volts will be recorded. The voltage of an exhausted cell is almost as large as a new one. Consequently, the voltage test of a dry cell furnishes no information as to its condition.

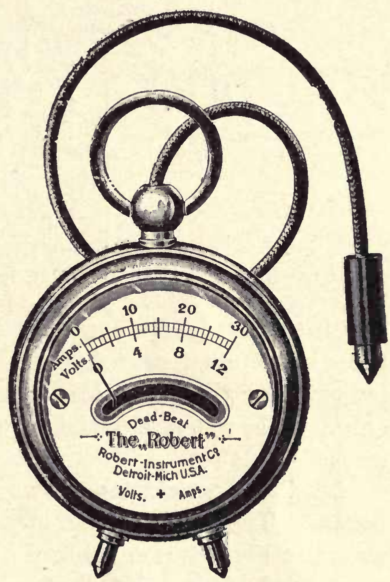


Fig. 62.—Roberts volt-ammeter.

The standard method of testing dry cells is to use an *ammeter*. This is a device that indicates the rate of flow of current in amperes. Figure 62 shows a combination voltmeter and ammeter, better known as a *volt-ammeter*. The flexible terminal is in both the ammeter and voltmeter circuits. When used to test dry cells, the flexible terminal and the terminal marked *amps* are touched to the dry cell terminals. The needle will move across the scale and indicate the current strength of the cell. If new, the reading for a No. 6 ignition cell will be between 25 and 30 amp. If the reading falls below 8, it shows that the cell is nearly exhausted and can not be considered as a reliable source of energy.

There is a perceptible difference in the action of cells at various temperatures. It is difficult for the chemical action to take place fast enough at a temperature of zero or below. On the other hand, heat stimulates the chemical action and may cause a rapid deterioration of the cell.

A rough test to determine if a cell is good can be made by short-circuiting the terminals momentarily by means of a wire. If a small arc can be drawn between the wire and the carbon post, the cell is in at least fair condition. The test can also be made by stretching a piece of thin copper wire of about No. 28 or 30 gage across the terminals. If it fuses instantly, it proves that the cell will test between 15 and 20 amp. with an ammeter. Another method is to rest a knife blade on the zinc post and to touch the tip of the blade to the carbon. If a small ring of smoke appears at the point, the cell is in fair condition.

It is often desired to know at what rate the current is flowing through an ignition coil. Figure 63 shows an ammeter properly installed in the

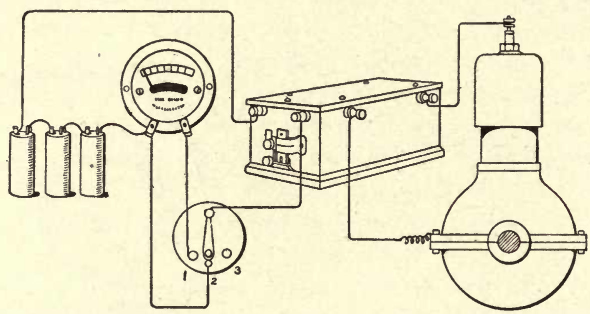


Fig. 63.—Installation of ammeter for testing current consumption of spark coil.

circuit to measure the current. When the switch lever is on point No. 1, the current must pass through the ammeter and the amperage will be indicated on the dial. Many coils can be adjusted to take as low as ½ amp., while others may be improperly adjusted to consume 2 or more amp.

44. Cell Connections.—Two or more cells connected together form a *battery*. The total voltage of a number of cells connected in series, as shown in Fig. 64, is equal to the voltage of a single cell multiplied by the number of cells, provided, of course, they are all alike. It is never good policy to connect cells of different types or ages, because they are quite sure to deteriorate at different rates. If one cell becomes exhausted while the remaining ones are good, the whole series will be rendered useless until the bad cell is replaced by a good one. A periodic test can be made by means of a battery ammeter to locate the defective cells.

A dry cell has an internal resistance of about 0.05 ohm when new. The *ohm* is the unit of resistance and is the opposition offered to the passage of one ampere of current at a pressure of 1 volt. As the cell grows older, the internal resistance increases, due to exhaustion of the chemicals and to a coating on the interior of the zinc cup. The effect of a high-resistance cell in a series group, then, is to prevent the flow of sufficient current. The good cells are not harmed by such a condition, as will be seen by replacing the defective cell by a good one.

The arrangement of a number of cells connected in parallel is shown in Fig. 65. This gives the voltage of one cell and a current capacity equal

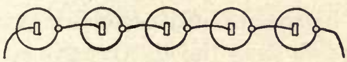


FIG. 64.—Cells in series.

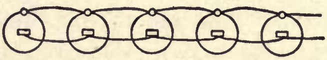


FIG. 65.—Cells in parallel.

to the sum of that of the different cells. This arrangement is seldom seen in ignition work.

Another combination sometimes used consists in connecting the cells in a multiple-series group. The arrangement is shown in Fig. 66. In the arrangement shown here, if the total current is 0.6 amp. each series group will supply only 0.2 amp. Experiments have proved that a set of cells will last much more than twice as long if the current demanded of them is only one-half as great, and much more than three times as long if the current demand is only one-third as great. Consequently, this arrangement is satisfactory, provided the cells deteriorate at the same rate. If they do not, there will be a flow of current locally in the cells which will reduce their efficiency.

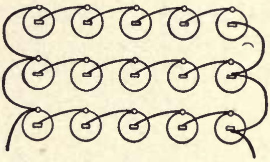


FIG. 66.—Multiple-series connection of cells.

A scheme of using two distinct sets of cells is often employed as shown in Fig. 67. By means of the three-point switch, the two sets of

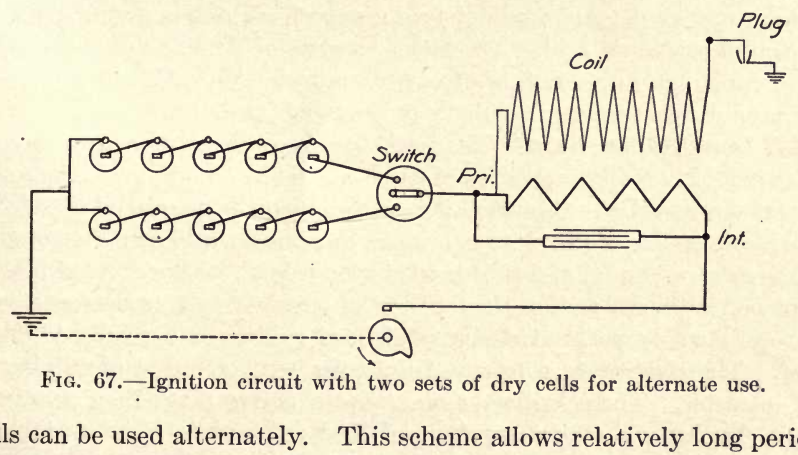


FIG. 67.—Ignition circuit with two sets of dry cells for alternate use.

cells can be used alternately. This scheme allows relatively long periods for recuperation.

45. Care of Dry Cells.—Dry cells are subject to a trouble known as *local action*. Unless the zinc of which the container is made is very pure, there will be small local cells set up wherever there is any impurity, such as particles of iron. In any cell one of the elements is attacked, and in these local actions the zinc is destroyed. The moisture rapidly finds its way out of these openings, and as a result the cell dries out and becomes worthless.

If the cells are located in a damp place, there is a possibility of the paper covers absorbing enough moisture to set up a local circuit between the cells. This means that the cells will be continuously discharging.

In order to avoid deterioration of the cells from the above causes, it is necessary to avoid wet locations for the cells, if possible. Cells for such locations, however, can be protected to a great extent by being imbedded in paraffin. With this arrangement, local discharge can not take place neither can any moisture escape through any holes in the zinc which may result from local action.

46. Storage Cells.—In storage cells the current results from chemical action, as in any primary cell. When the cells are exhausted, however, they are not discarded or replaced by new elements, but instead are restored to normal condition by passing through them a direct current from some outside source. By this process a reverse chemical change takes place, restoring the elements to their original structure. It is erroneous to say that *electricity* is stored in them. In reality, the storage cell is a device which converts electrical energy into chemical energy during charge, and during discharge reconverts the chemical energy into electrical energy. The charge is, therefore, in the form of chemical energy. When current is drawn from the cell, the chemical action takes place, thus converting chemical energy into electrical energy. There are two kinds of storage cells in use, the lead type and the nickel-iron type. The former consists of two groups of lead composition plates immersed in a solution of sulphuric acid. The latter consists of elements of nickel and iron compounds in a solution of caustic potash. In addition, the cells may be put up in either stationary or portable form.

47. Lead Storage Cells.—The lead storage cell consists of two sets of plates placed in a dilute solution of sulphuric acid. In the positive group the plates are lead grids in which the openings have been packed with lead peroxide, characterized by its chocolate brown color. The plates of the negative group consist of finely divided sponge lead. These sets of plates are placed in the cell so that the positive and negative plates alternate and are separated by perforated sheets of hard rubber or specially treated wood. The electrolyte consists of a 10 per cent. solution of sulphuric acid in water. There is always one more negative plate than positive. Figure 68 shows a stationary type of lead cell with a glass container. When the cell is used as a source of current the acid acts on the plates, forming lead sulphate. The hydrogen from the acid forms water in combination with the oxygen from the lead peroxide of the positive plates. A single lead cell gives a pressure of about 2 volts and a current depending upon the size and the number of the plates. For ignition purposes three cells in series are generally used, giving about 6 volts.

When a cell is to be charged a direct current is passed through it in the opposite direction. The positive element is reconverted into lead peroxide, the negative into sponge lead, and the sulphuric acid is returned to the solution. As the acid is heavier than water, the electrolyte gradually becomes heavier as the battery is charged and the condition of the charge can be determined by the gravity of the solution.

During discharge both elements partially change to lead sulphate and assume a light grayish color. If the process were continued too long and

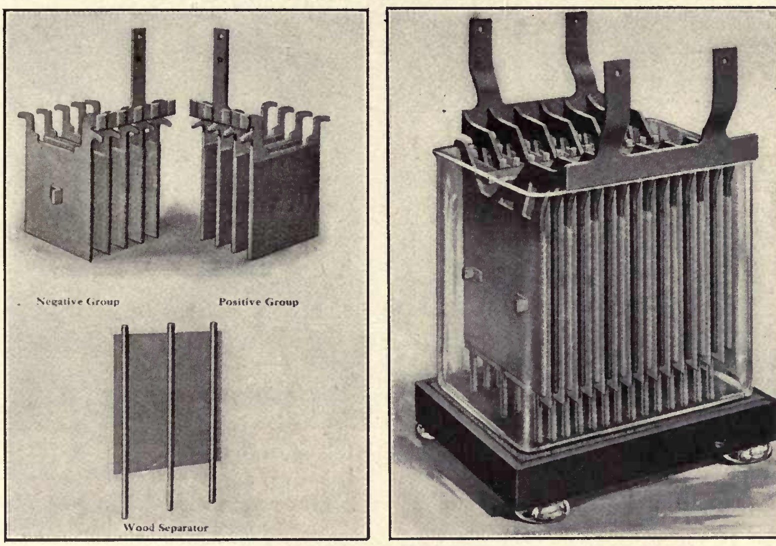


FIG. 68.—Stationary type of lead storage cell.

the cell exhausted, both plates would be made up of large masses of lead sulphate. It is very injurious to allow this to happen, as lead sulphate is an insulator and when formed in such large quantities it is practically impossible to break it down and to restore the plates by recharging.

A sectional view of a portable storage cell such as used on automobiles is shown in Fig. 69. The construction of the portable cell allows but a small space for the electrolyte. For this reason the specific gravity of the solution has a wide range between charge and discharge, being respectively about 1.285 and 1.150.

In the top of the cell is located an expansion chamber to take care of changes in volume of the solution during charge and discharge. The chemical action which takes place produces some heat which causes the liquid to expand. The liquid will evaporate and care must be taken to keep the plates covered with the solution or the capacity of the cell will be reduced. A filler plug is shown at the center of the figure. Only distilled water should be used, as the mineral contents of other water may seriously affect the action of the cell. After a cell has been in use for

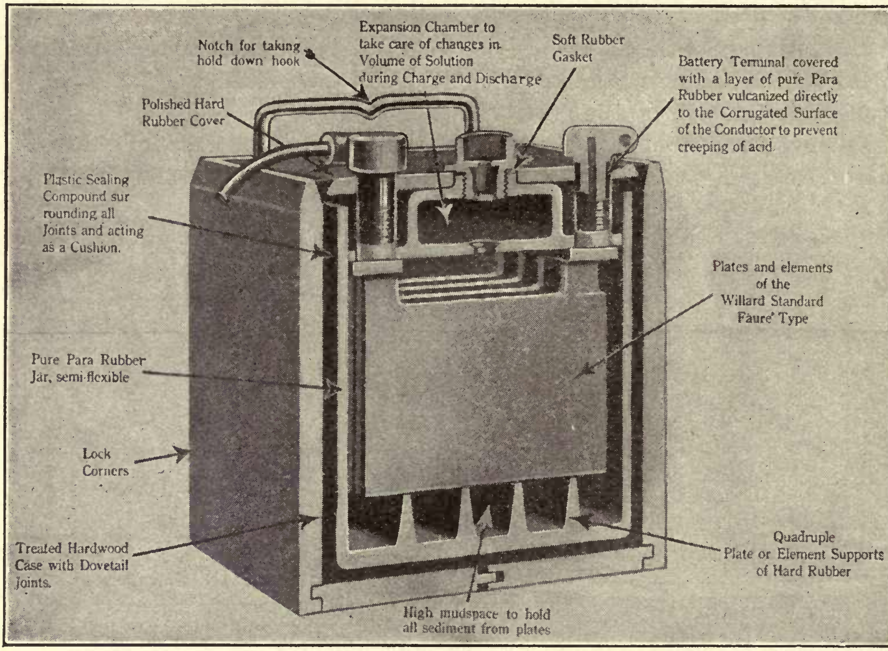


FIG. 69.—Section of portable storage cell.

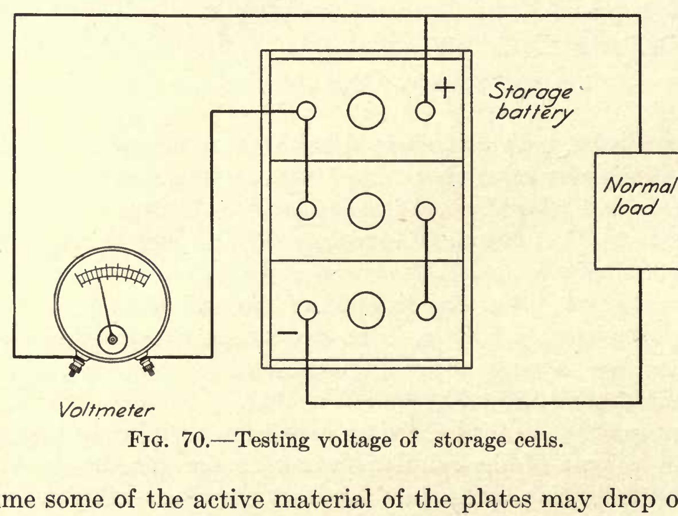


FIG. 70.—Testing voltage of storage cells.

some time some of the active material of the plates may drop off. The mud spaces below the plates are provided to take care of this material without its touching the plates. Otherwise it might establish an electrical connection between the plates and cause the cell to discharge rapidly through this internal circuit.

When a lead cell is charged it should show about 2.2 volts. It is considered discharged when its voltage has dropped to 1.8 volts. This can be determined by making a test with a voltmeter while the cell is in service. Figure 70 shows the method of making this test. Each cell in the battery should be tested separately, as it often happens that one cell will need more attention than the others. As shown here three cells are built into a single battery unit, the cells being in series. The voltmeter is shown connected to read the voltage of but one of the cells.

It is out of the question to use a battery ammeter for testing storage cells. The capacity of the storage cell is too great for an ordinary battery ammeter and the instrument would doubtless be destroyed.

48. Hydrometer Test.—Another reliable test involving the use of an inexpensive equipment is to use a hydrometer to test the specific gravity of the electrolyte. The battery hydrometer, as shown in Fig. 71, has an outside glass tube fitted with a small tip and a rubber bulb to act as a syringe so that some of the electrolyte may be drawn up into the tube. Inside this tube is a glass float which will sink in the electrolyte to a greater or less amount depending on the specific gravity of the electrolyte. When we say that the specific gravity of a solution is 1.21 we mean that the liquid is 1.21 times as heavy as water. The scale reading on the hydrometer stem at the surface of the liquid when the hydrometer is floating in it indicates the specific gravity of the liquid.

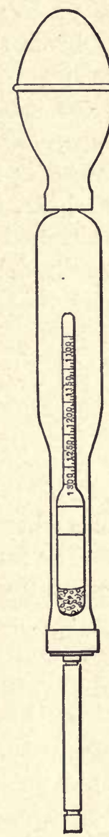


Fig. 71. Hydrometer syringe.

The commercial type of hydrometer is constructed to read correctly at a temperature of 70°F. Consequently, if the temperature of the solution is other than 70°, corrections will have to be made to the readings obtained. The rule is that for every 3° above 70°F., 0.001 shall be added to the hydrometer reading; and for every 3° below 70°F., 0.001 must be subtracted from the observed reading. For example: The temperature at end of charge is 120°F. and the observed gravity reading is 1.260. The corrected reading is determined as follows:

$$120° - 70° = 50°$$
$$50 \div 3 = 17$$
$$17 \times 0.001 = 0.017$$
$$\text{Corrected reading: } 1.260 + 0.017 = 1.277.$$

If the reading at 0°F. is 1.210, then

$$70° - 0° = 70$$
$$70 \div 3 = 23$$
$$23 \times 0.001 = 0.023$$
$$\text{Corrected reading: } 1.210 - 0.023 = 1.187$$

From the above it can be seen that temperature must be taken into consideration, otherwise the hydrometer reading would be misleading.

49. Storage Cell Ratings.—The capacity of a cell is always stated in *ampere-hours.* By ampere-hour is meant the quantity of the electricity flowing in 1 hour at a rate of 1 amp., or in 10 hours at a rate of $\frac{1}{10}$ amp. In short, the number of ampere-hours is equal to the rate in amperes multiplied by the number of hours. A cell rated at 60 amp.-hr. will usually deliver about:

Amperes		Hours
7.5	for	8
5.0	for	14
3.0	for	27
1.0	for	90

This means that a cell is more efficient during a low rate of discharge than when the rate is high.

The number of cells in a battery has nothing to do with the ampere-hour rating, because the cells are connected in series, which increases the voltage only. Ignition batteries are usually made up in two-cell and three-cell sets. The ampere-hour capacity may be the same for both, usually 40 or 60, but the voltage would be 4 and 6 volts respectively.

50. Edison Storage Cells.—A storage cell to overcome the objectionable features of lead storage cells, such as heavy weight, acid fumes, and rapid deterioration, has been developed by Thomas A. Edison. The electrodes are composed of iron and nickel, the container is nickel-plated steel, and the electrolyte is a solution of caustic potash.

The negative element, Fig. 72, consists of a steel grid containing pockets filled with iron oxide. Figure 72*a* shows a pocket for a negative plate. The positive element, Fig. 73, consists of thirty perforated steel tubes reinforced by steel seamless rings equidistantly spaced and mounted on a steel grid. Each perforated tube, Fig. 73*a,* is filled with alternate layers of nickel hydrate and flake nickel. During charge and discharge, the solution of caustic potash transfers oxygen from one element to the other.

The advantages of the nickel-iron cell are its mechanical strength and relatively high output per pound of cell. The voltage of the cell is, however, only about one-half as high as that of the lead cell and falls quite low at freezing temperature.

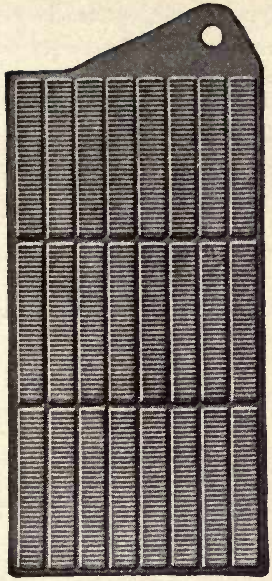


FIG. 72.

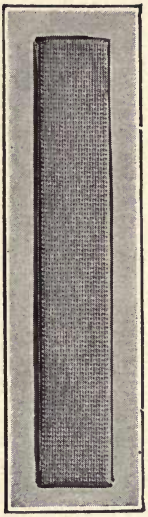


FIG. 72a.

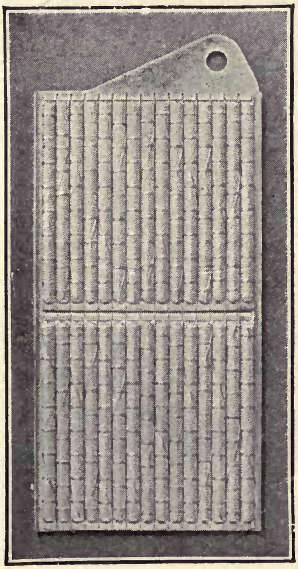


FIG. 73.

FIG. 73a.

51. Methods of Charging.—In the modern electrically equipped automobile, the battery is charged by an electric generator driven by the

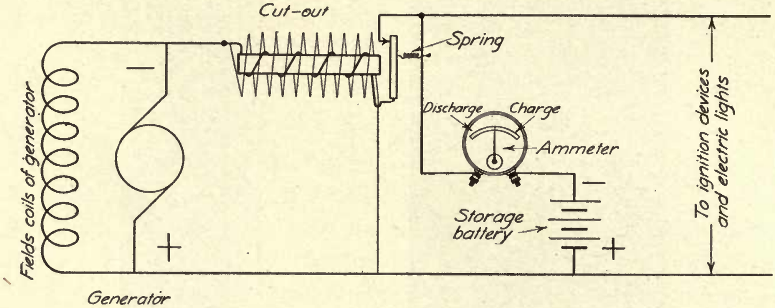


FIG. 74.—Connections of storage battery and generator with automatic cut-out.

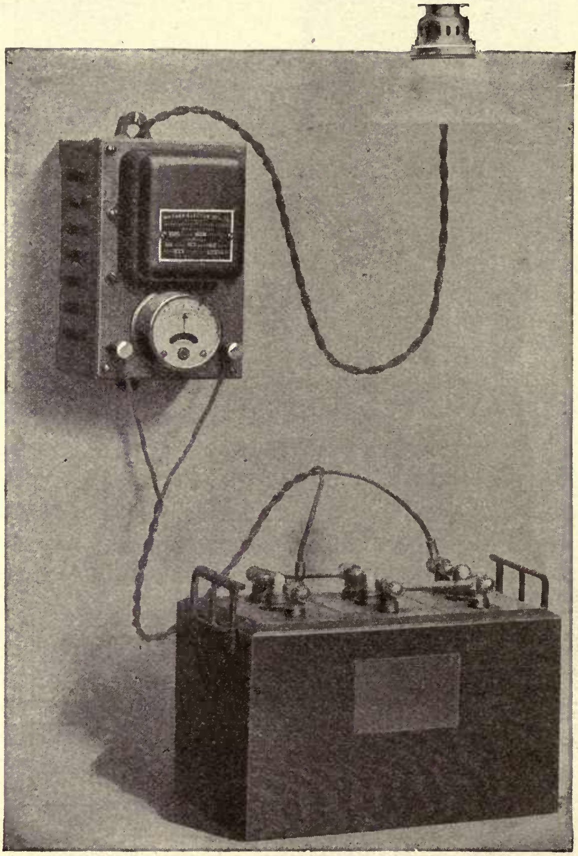


FIG. 75.—Wagner rectifiercharging storage battery.

engine. The equipment is so designed as to operate automatically, and to maintain the batteries always in a charged or nearly charged condition.

There are various methods of charging lead batteries. In modern automobiles, a low-voltage direct-current dynamo generates the charging current at a pressure slightly above the voltage of the storage battery. Figure 74 is a diagram of the electrical connections of one type of generator. A generator is represented here as charging the battery. The *cut-out* is a device which connects the generator and storage battery as soon as the voltage of the generator exceeds that of the battery. When-

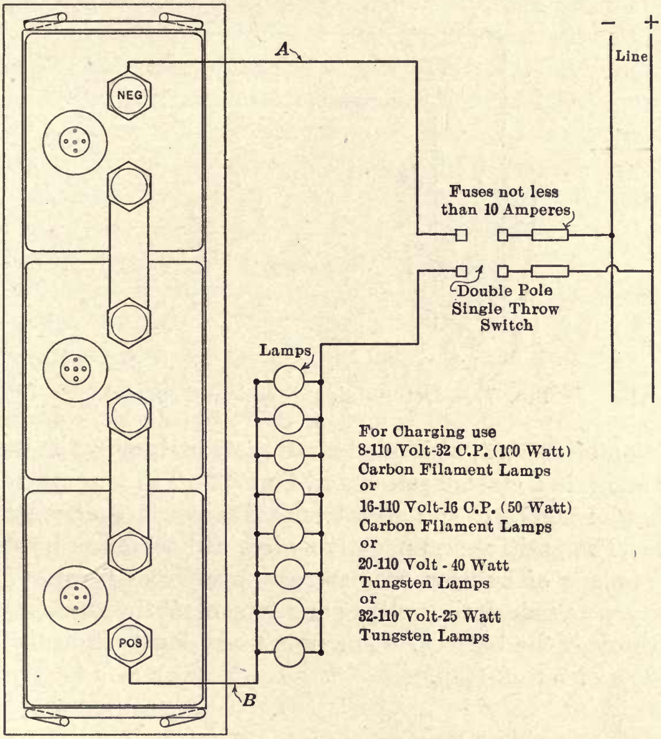


FIG. 76.—Connections for charging storage battery from 110 volt direct-current circuit.

ever the generator voltage falls below that of the battery, the cut-out disconnects them, thereby preventing a discharge from the battery through the generator.

Batteries can also be charged from an alternating-current lighting circuit by means of a rectifier, Fig. 75. The rectifier is a device that converts the alternating current at a pressure of 110 volts into direct current at a pressure of about 10 volts. An ammeter is included in the device to show the rate of charging. If the battery is charging at a rate of 3 amp., it will take about 24 hours to charge a 60 amp.-hr. battery. The end of charge, however, is best determined by the gravity reading as indicated by the hydrometer.

One other method can be used provided there is an available source of *direct* current. Figure 76 shows the method of making connections. The objectionable feature of this method is the waste of so much energy in the lamp resistance, while only a small portion is stored in the battery. It is quite necessary to have the light mains connected properly to the battery terminals, that is, the positive main must be connected to the positive battery terminal. If no instruments are at hand to determine

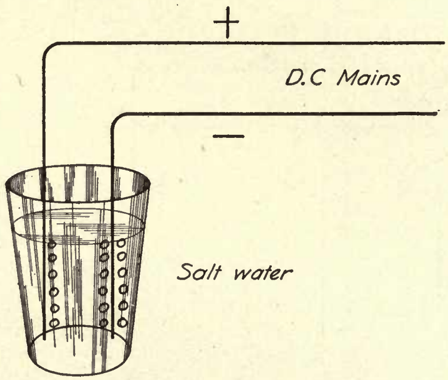


FIG. 77.—Determining direction of current.

the direction of current, a simple test consists in dipping the terminals of the light mains in a glass of salt water, Fig. 77. Twice as much hydrogen gas will be given off by the negative terminal as oxygen gas from the positive terminal. The positive and negative wires can therefore be determined by the numbers of bubbles that are given off from them. The lamps are necessary to reduce the voltage and to control the amount of current flowing through the battery. The number of lamps indicated allows a current flow of 7 to 8 amp.

CHAPTER V

LOW-TENSION MAGNETOS—ARMATURE TYPE

52. The Low-tension Magneto.—The low-tension magneto may be used with any of the general forms of ignition system previously described, the magneto merely serving as a mechanical means of generating the low-tension or primary current instead of using a battery current. As will be shown, however, the current generated in a magneto is usually an alternating current instead of a direct current (always flowing in one direction) such as is obtained from batteries. A low-tension magneto may be used with a make-and-break ignition system, with a vibrating coil jump-spark system, or with a non-vibrating coil system.

In the preceding chapters, we have seen the effect of passing an electric current through a coil of wire in setting up a magnetic field and in magnetizing an iron core within the coil. A magneto may be said to reverse this process, the magnetic field from a permanent steel magnet being used to generate an electric current in a wire. In our previous discussions of induction coils we have used a battery current to energize the core of our coil or build up its magnetic field. By interrupting the battery current we destroyed or removed this magnetic field and in so doing induced a current in the windings surrounding the core. First, a current was passed through the coil, thus building up the magnetic field; then, the field was destroyed and a current induced in the windings of the coils. In a magneto, we use permanent steel magnets to set up a magnetic field through a coil of wire; then, by moving the coil of wire, or by some other mechanical means, the magnetic field is given another path, not through the coil, thus having the same effect in inducing a current in the winding of the coil as did the destruction of the field in the case of the induction coil.

In the armature type of magneto, a coil of many turns of insulated copper wire is wound around an H-shaped soft-iron core. This is called the armature and is mounted so that it can be revolved between the ends or pole pieces of U-shaped permanent magnets. As the armature revolves, electric impulses are set up in the winding. In the low-tension type of magneto, the windings are such that the current thus generated is of low voltage.

53. Magnets and Magnetism.—A discussion of magnetism and its relation to electricity will help to an understanding of the action of magnetos. Under certain conditions a piece of iron or steel acquires the property of attracting other pieces of iron or steel. This property of attracting iron or steel is called magnetism, and a body possessing it is called a magnet. Iron or steel, being the only metals which show decided magnetic properties, are the only ones commonly used in the manufacture of magnets, and are the only ones which will be considered here.

A straight magnet, when suspended so that it is free to move, will swing into a north and south position, thus showing that the earth is

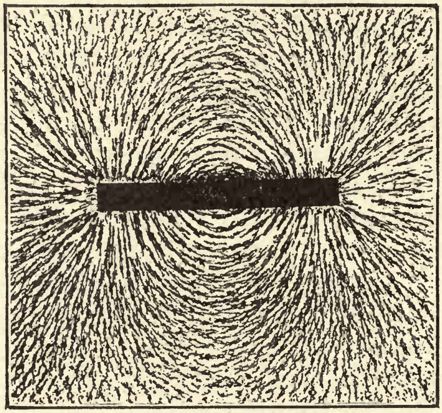


Fig. 78.—Field of a bar magnet as shown by iron filings.

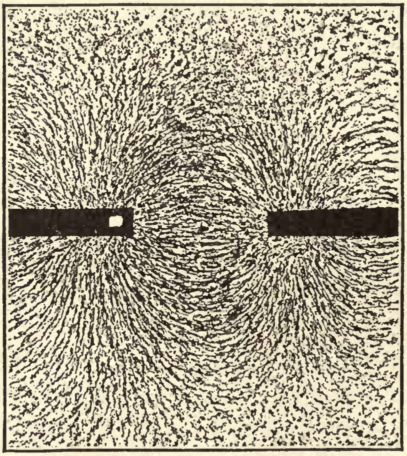


Fig. 79.—Field between unlike poles of two magnets, showing attraction.

itself a magnet. This is best illustrated by the compass, which has a small steel magnet for its needle. The end of the magnet which points to the north is called the north pole of the magnet, while the other end is called its south pole.

Soft iron loses its magnetism as soon as the magnetizing force is removed, while hard steel after being magnetized will, with proper treatment, remain magnetized indefinitely. For this reason temporary magnets, such as used in the cores of induction coils, are made of soft iron or annealed steel, while permanent magnets, such as the magnets of a magneto, are made of hard steel.

54. Lines of Force.—Certain parts of a magnet possess the power of attracting iron to a much greater extent than other parts. These parts

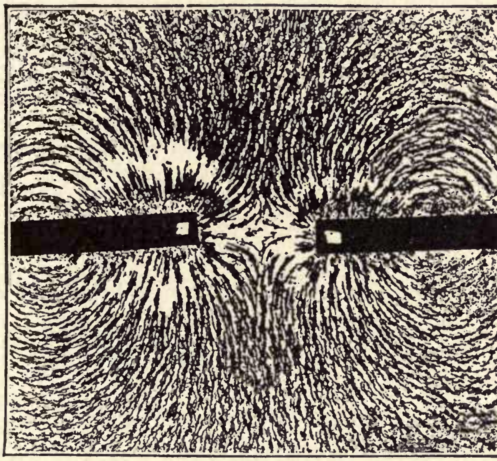


FIG. 80.—Field between like poles of two magnets, showing repulsion.

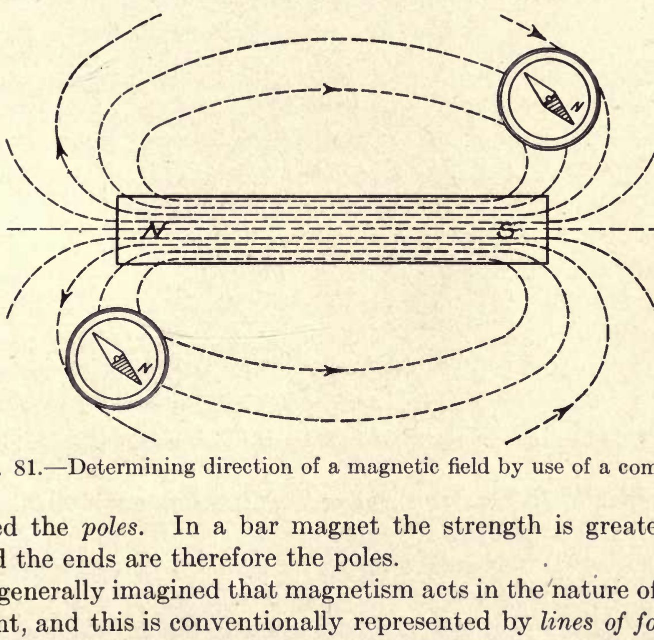


FIG. 81.—Determining direction of a magnetic field by use of a compass.

are called the *poles*. In a bar magnet the strength is greatest at the ends and the ends are therefore the poles.

It is generally imagined that magnetism acts in the nature of a stream or current, and this is conventionally represented by *lines of force* which always flow out of the north pole of the magnet and around and into the south pole, forming a complete circuit. The reason for this idea is readily seen by placing a piece of paper over a bar magnet and sprinkling iron filings over the paper. The action of the magnetic force will arrange the filings in lines running from one end of the magnet around to the other end, as shown in Fig. 78. These lines will be seen to radiate from near the ends or poles of the magnet. Even those lines which appear

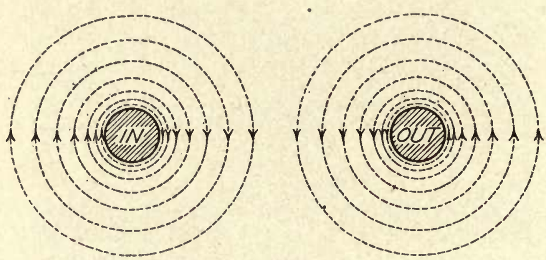


FIG. 82.—Showing magnetic field around electric wires.

to run straight out from the ends would be found to swing around and enter the other end if the paper were large enough.

When two magnets are brought together, it is found that the north pole of one attracts the south pole of the other, and that two like poles will repel each other. In Fig. 79 is shown the arrangement of lines of force, as shown by iron filings, between a north pole and a south pole

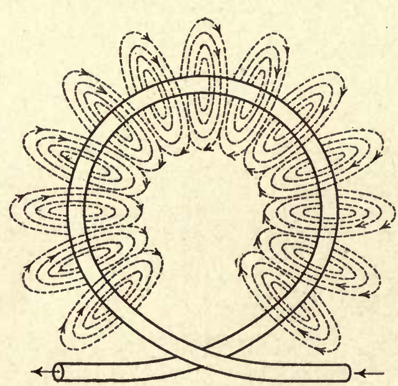


FIG. 83.—Showing magnetic field produced by current in a single loop.

of two magnets. In Fig. 80 is shown the arrangement of the lines when two like poles are placed near together.

If a compass is held in the field of a magnet, its north pole will be repelled by the north pole of the magnet and will be attracted by the south pole. A compass will therefore indicate the direction of the lines of force at any point in the field of a magnet, as shown in Fig. 81.

55. Electromagnetism.—A wire carrying an electric current always produces a magnetic field at right angles to the direction of flow of the current. This fact constitutes the basis of the relation between electricity and magnetism. This magnetic field is arranged in concentric circles around the wire, as in Fig. 82, and, like the field of a magnet, its direction can be determined by a pocket compass. The relation of the direction of the current flow to the magnetic field is shown in Fig. 82.

If the wire is coiled into a loop, as in Fig. 83, we find that the lines of force all enter the same face of the loop and come out of the other face. If two loops are placed close together, the lines join and go around the two wires together instead of around each one alone. If we wind a number of turns of wire into a coil or solenoid, as shown in Fig. 84, nearly all the lines of force will enter one end of the coil, pass through it, leave

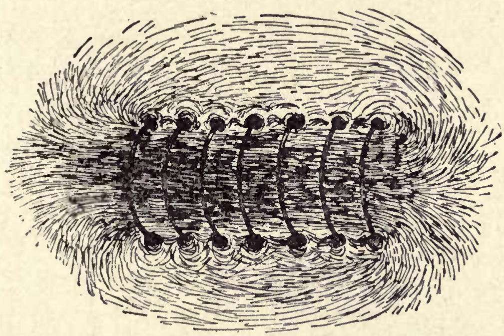


FIG. 84.—Showing magnetic field of a solenoid.

the opposite end, and return through the air to the starting point. Thus we see that a solenoid or coil bearing an electric current has the same character of field as a bar magnet, and has a north pole where the lines of force leave the coil and a south pole where the lines of force enter the coil. The following rule may be used for determining the polarity, or direction of the lines, of a coil or solenoid.

Rule.—If the coil be grasped in the fingers of the right hand with the fingers pointing in the direction of the flow of the electric current and with the thumb extended at right angles to the fingers, the thumb will point in the direction of the north pole, or the direction in which the lines of force pass through the coil.

An electromagnet made in this way is not very strong, but may be made so by inserting a core of soft iron or steel. The iron is capable of carrying or conducting magnetic lines many thousands of times more readily than air. Hence, a solenoid with an iron core will be several thousands of times greater in strength than a simple solenoid without the core.

The fields of motors and generators, transformers, induction coils, etc., are all built upon soft-iron cores for this reason. A piece of hardened steel may be made into a permanent magnet by passing a current through a coil surrounding it.

56. Horseshoe Magnets.—In Fig. 85 is shown the magnetic field around the ends of a horseshoe or U-shaped magnet, as shown by iron filings on a sheet of paper over the magnet. By bringing the ends of the magnet near together in this manner the lines of force are concentrated. In magneto operation the field is even more concentrated by the soft-iron armature between the pole pieces. The armature provides a path of low resistance for the passage of the magnetic lines and thus concentrates the field between the poles.

A "magnet keeper" of soft iron or steel is generally provided with a horseshoe magnet, its use being to prevent loss of magnetism by the magnet. When a keeper is used, as shown in Fig. 86, a large increase

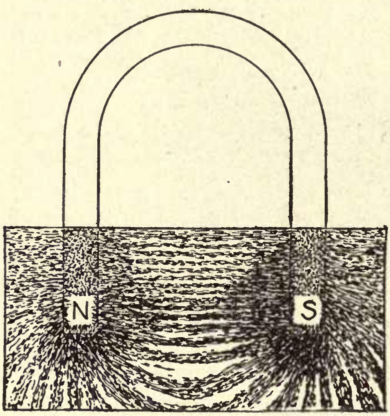


Fig. 85.—Field of a horseshoe magnet as shown by iron filings.

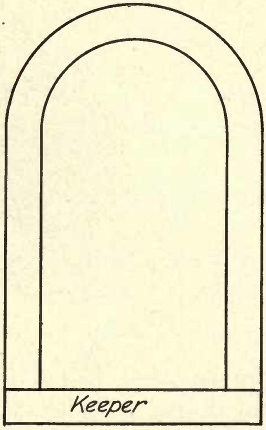


Fig. 86.—Horseshoe magnet with keeper.

of the magnetic flux or current is produced in the iron and the strength of the magnet is not dissipated. When a magnet has a keeper on it, it will attract other pieces of iron but feebly, because the lines of force pass through the keeper instead of through the air. In a magneto or electric generator, the armature takes the place of the keeper and produces a similar effect. If a magnet is removed from a magneto for any reason, a keeper should be placed across the pole pieces to prevent its losing its magnetism. It has been found by experience that overheating or jarring a magnet causes it to lose its strength. When first magnetized, a jar or blow causes quite a decrease in strength, but the amount lost by each succeeding jar becomes less and less. Magnets used for such purposes as in magnetos must be put through some aging process so that the magnets will be reduced to a constant strength.

It must be borne in mind that excessive heating or rough treatment or leaving a magnet without a keeper will permanently injure the best of magnets, hence care should be used in handling them.

57. Compound Magnets.—The permanent magnets used in magneto construction are generally not made of a single piece, but of from two to eight U-shaped magnets closely fitted together as shown in Fig. 87. The south poles of all the magnets are placed on one side and the north poles on the other side. Magnets made in this way are much stronger and retain their magnetism longer than a single magnet, while the magnetic flux through the armature is made much more intense.

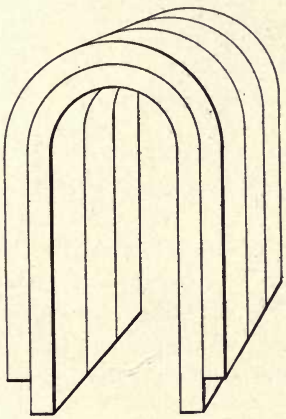


Fig. 87.—Compound magnet.

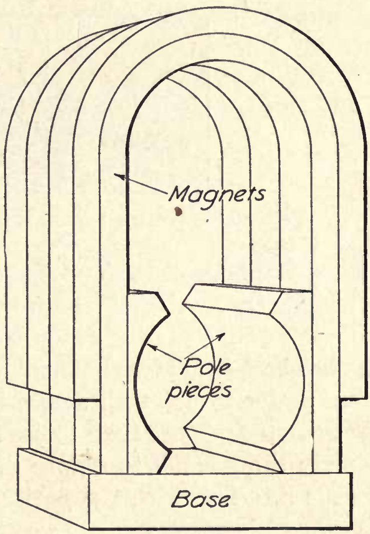


Fig. 88.—Magnets, pole pieces and base of magneto.

In magneto construction, the poles of the magnets are fitted with "pole pieces" which receive the magnetism from the ends of the magnets and concentrate it through the armature. (See Fig. 88.) The inner ends of the pole pieces are bored to a few thousandths inch larger than the armature, the air gap being kept as small as possible to reduce the resistance to the magnetic flux. The base of the magneto must be of some non-magnetic material so that the field will go through the armature and will not be diverted through this base. The armature is made of a number of pieces of thin soft iron, as the magnetism of the armature is constantly changing as it is revolved between the poles of the magnets.

58. Principles of Electric Generation.—The essential parts of a low-tension magneto are: The magnets and pole pieces, the armature, and a non-magnetic base for supporting the magnets, pole pieces, and armature. In addition, for jump-spark ignition purposes on a multi-cylinder engine, there are the circuit-breaker and the distributor. In some makes, the condenser is located in the magneto; in others, it is located in the coil.

In all magnetos, the production of an electric impulse is due to repeatedly varying the number of magnetic lines of force that thread through the soft iron core of the armature coil. This may be accomplished either by rotating the armature coil within the field or by keeping the coil stationary and revolving an "inductor" between the pole pieces in such a way as to rapidly change the direction of the field through the coil.

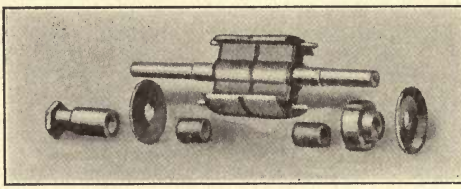


Fig. 89.—Construction of armature core of "Wizard" magneto.

This chapter will take up the shuttle type of magnetos, in which an armature carrying the coil is revolved within the magnetic field. Figure 89 shows the construction of the armature core of the "Wizard" magneto, with the sheet-iron plates assembled over the central steel shaft. Some makers prefer to use stub shafts fastened into brass plates at each end of the armature rather than to use the solid shaft extending clear through. The main thing is not to reduce the area of the laminations at this point and thus interfere with the path of the magnetic flux through the core.

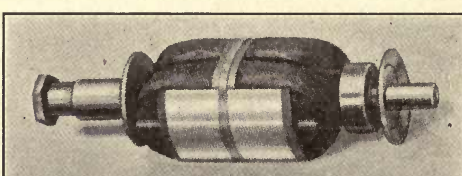


Fig. 90.—Complete armature of "Wizard" magneto.

In the type shown here, this is avoided by enlarging the laminations where the shaft passes through them. In Fig. 90 is shown the armature assembled with the coil or winding over the core. In winding an armature, one end of the winding is usually grounded to the shaft and the other end connected to an insulated "collector ring" from which the current is taken, as the armature revolves, by a copper or carbon brush rubbing on the collector ring. In some types of magneto ignition systems, the current from the grounded end of the armature winding must also be collected by a brush rubbing on the shaft or some other metal part of the armature, since the film of oil in the bearings might prevent the passage of the current through it.

Figure 91 shows a section of a magneto with the armature in different positions between the pole pieces. The closely cross-hatched sections represent the wires of the armature winding. In the first position, the magnetic lines of force or flux pass through the winding of the armature. In the second position, the flux still passes through the armature coil, but with slightly diminished strength. In the third position, the flux passes across the ends of the armature core and does not go through the winding. In the fourth position, the armature has turned so that the flux passes through the winding in the opposite direction. The greatest

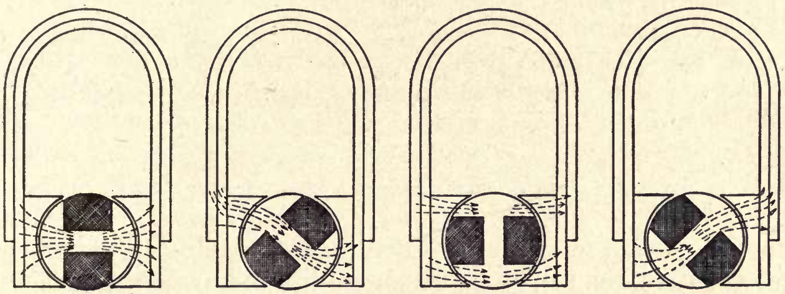


FIG. 91.—Showing changes of magnetic flux during rotation of armature.

voltage is generated as the armature goes from the second position to the fourth position, the maximum being found in a position near the third, when the flux is removed entirely from the winding. It will be seen that turning the armature to this position has the same effect as interrupting the magnetizing current through a coil, the passage of the magnetic field through the core being suddenly stopped.

59. Current Wave from a Shuttle-wound Armature.—Figure 92 shows a typical curve of the current generated in the winding of an armature of this type as it is revolved. In Fig. 93 are shown the positions of the armature corresponding to the points *A*, *B*, *C*, *D*, and *E* of Fig. 92. In position *A* the flux is passing through the armature in one direction, while in position *B*, after turning 180°, the flux is in the other direction, because the armature has turned around. During the remainder of the revolution, from position *E* around to position *A*, the current generated will be opposite in direction to that generated during the first half of the revolution. To show this on Fig. 92, the current generated during the first half of the revolution is shown by the height of the curve *above* the base line, while that generated during the second half is shown *below* the line.

The exact positions of the armature at which the strongest electrical impulse can be obtained, and the shape of the current wave, vary with change in the forms of the pole pieces and armature core, as well as with the speed of rotation and the strength of the magnets. Any change in one of these factors will produce a change in the electric pressure at the terminals of the armature winding.

Most magnetos that are run at variable speeds are so constructed that a strong current can be produced through a considerable range of position of the armature. This is done to allow for the advance and retard of ignition relative to the position of the pistons, as well as to allow

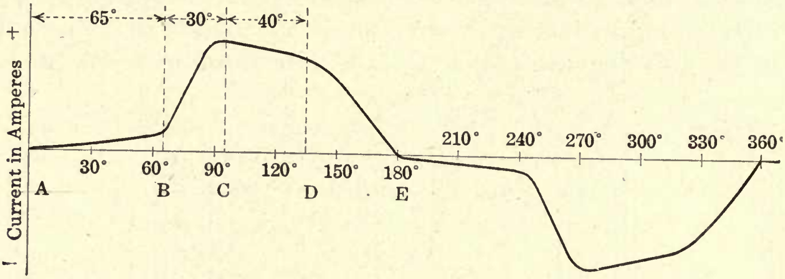


Fig. 92.—Typical curve of current from shuttle armature.

for the lag of the current in the armature with regard to the position of the armature at the instant of maximum impulse or voltage. This lag is small enough for the speeds in usual practice, so that in a general way the positions of the armature for the maximum current are about as indicated in Figs. 92 and 93.

It is evident from the current wave diagram of Fig. 92 that, whatever the system of ignition with which a low-tension magneto is used, the best spark will be produced only during the angle of rotation in which the current generated is at or near its maximum. When the armature

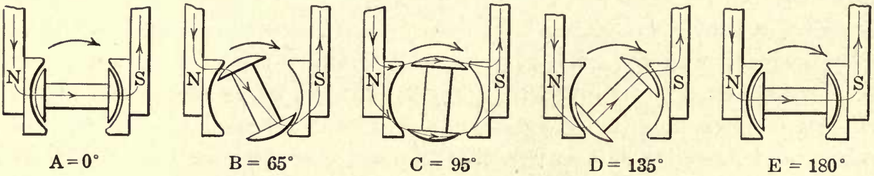


Fig. 93.—Armature positions of Fig. 92.

is in position *C* (Fig. 93) the current is at its maximum and the spark will be strongest. As the armature rotates from position *C* to *D* the curve decreases slowly in height; hence, during this period the current produced is most favorable for ignition purposes. Position *C* would correspond to extreme advance and *D* to extreme retard for this magneto, giving a spark range of about 40° of armature rotation. It is evident from the shape of the curve that a position of advance beyond *C* or of retard beyond *D* would give too poor a spark for ignition purposes or no spark at all. This shows the necessity of having an alternating-current magneto gear-driven from the engine shaft, so that the armature will always be in the desired position with relation to the pistons. The curve of Fig. 92 also shows that there are two points in a revolution of this type of armature during which a spark can be obtained, namely: between *C* and *D* as just mentioned, and at a similar position 180° later, when the current is in the other direction. Consequently, we find that the armature speed of a magneto bears a definite relation to the number of cylinders of the engine. In a four-cylinder four-stroke engine, the armature must revolve at crankshaft speed, in order to produce four sparks during two revolutions of the crankshaft. On a six-cylinder four-stroke engine, the armature must make three revolutions during two revolutions of the crankshaft, or it must turn at one and one-half times crankshaft speed. In a single-cylinder four-stroke engine the magneto might be driven at one-fourth crankshaft speed, although more often it is driven at crankshaft speed and only one of the four current waves generated during the two revolutions is used for ignition. This is done in order to give the magneto a better rotating speed, as the voltage and current generated depend on the speed of rotation.

60. Low-tension Magneto with Make-and-break Ignition.—The use of the magneto as a source of current for the ordinary make-and-break system of ignition constitutes the simplest application of the magneto. Nothing else is needed but the make-and-break igniter and the simplest type of magneto, gear-driven from the engine shaft, these being connected by a single insulated wire. Figure 94 shows the application of a Sumter magneto to a Fairbanks-Morse engine using make-and-break ignition. The armature of the magneto is driven at the same speed as the crankshaft of the engine and, as this is a single-cylinder four-stroke engine, the magneto will generate four current waves during the two revolutions of the engine, but only one of these will be used for ignition. The magneto armature is so set with relation to the crankshaft of the engine that the current generated is at its maximum at the desired instant for the spark. The current is collected from the insulated end of the armature winding and is led through the single wire to the insulated electrode of the igniter. The gap at the igniter being closed, the current flows across to the movable electrode and through the metal of the engine and magneto back into the armature winding, entering through the grounded end of the winding. No "kick" coil is needed, as the armature coil serves this purpose and gives a powerful induced current for the spark when the regular current is interrupted by the break of the circuit at the igniter.

Figure 95 shows an external view of this Sumter magneto with the driving gear removed. Figure 96 shows the same magneto partly in section. The current from the insulated end of the armature winding

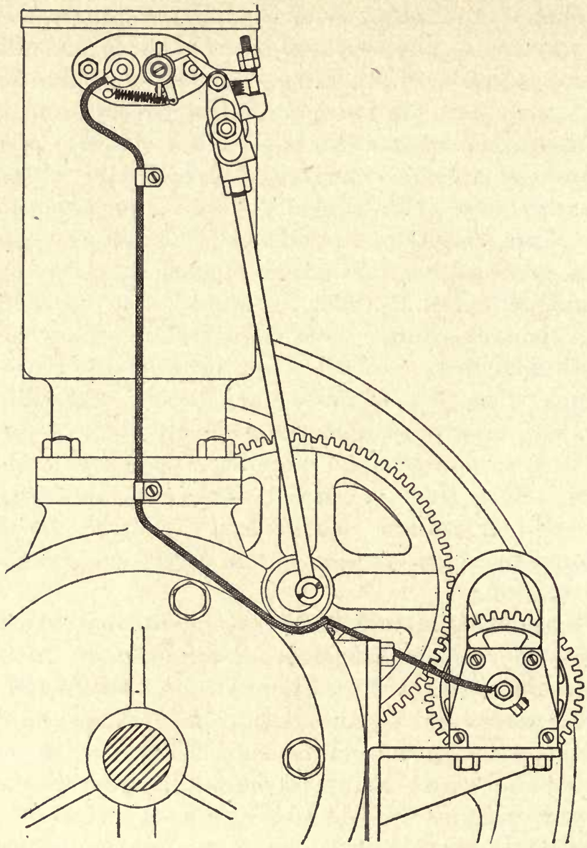


FIG. 94.—Mounting of magneto for make-and-break ignition.

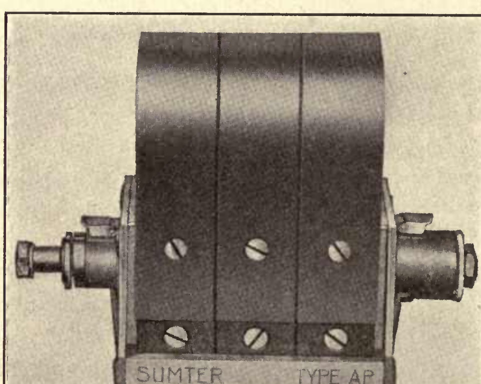


FIG. 95.—Exterior of Sumter magneto.

is carried through a wire in the hollow stub shaft at the left to a collector plate on the end of the shaft, from which it is taken by two brushes which rub on this plate. The two brushes serve the obvious purpose of insuring a good contact even though dust or dirt lodge under one of the brushes. The connection to the other end of the armature winding is made by a brush rubbing on the bronze end plate of the armature and thence through the metal of the armature to the grounded end of the winding. Since the magneto is fastened to the engine frame, there is thus established a complete grounded return for the current, from the igniter through the metal of the engine and magneto to the grounded end of the armature winding.

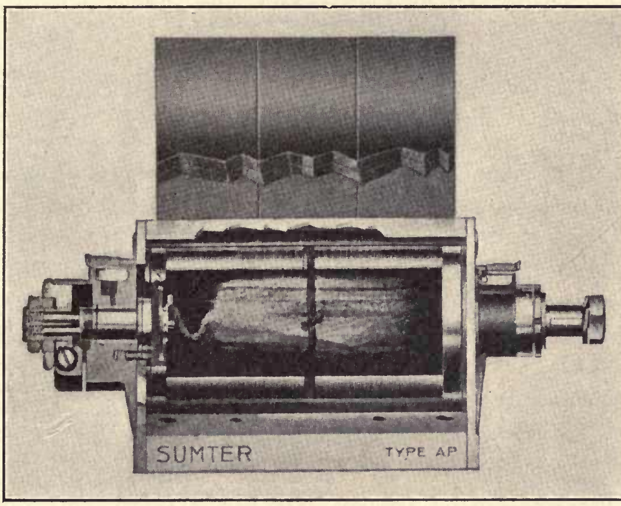


FIG. 96.—Partial section of Sumter magneto.

61. Battery Connections.—On large engines, it is sometimes inconvenient or impossible to turn the engine fast enough by hand to secure a satisfactory sparking current from the magneto. In such cases a battery and coil can be installed for use in starting. The method of connection is shown in Fig. 97. The insulated electrode of the igniter is connected to the central pole of a double-throw switch. One pole, *M*, of the switch is connected to the insulated terminal of the magneto; the other pole, *B*, is connected to the coil. The other end of the coil and battery system is grounded to any convenient point on the engine, thus establishing connection with the grounded movable electrode of the igniter.

Particular care should be taken that the connections to the switch are made so that it is impossible for any battery current to flow through the wire *W* and into the armature of the magneto. If battery current were allowed to flow through the armature winding it might set up a magnetizing force in the armature core opposite to that of the magnets, and thus destroy or weaken the strength of the magnets. When a magneto is seemingly "dead" it is evident that battery current has passed

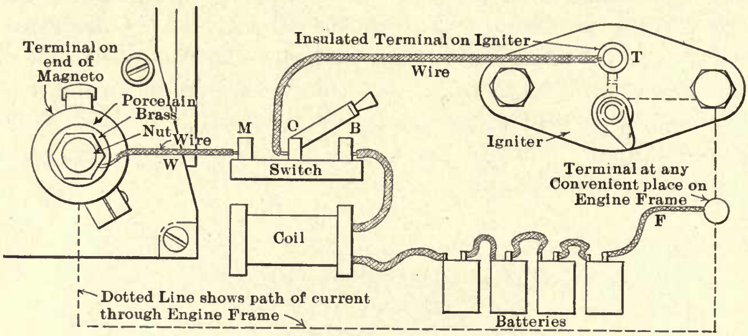


FIG. 97.—Connections for using either magneto or battery.

through it. Never connect a battery to an engine unless the wire to the magneto has first been taken off or unless a switch is used, as shown in Fig. 97.

Where a battery is not used, an ideal method of installing a switch for stopping the spark from a magneto is shown in Fig. 98. The ignition is stopped by *closing* the switch. This gives the magneto current an easy

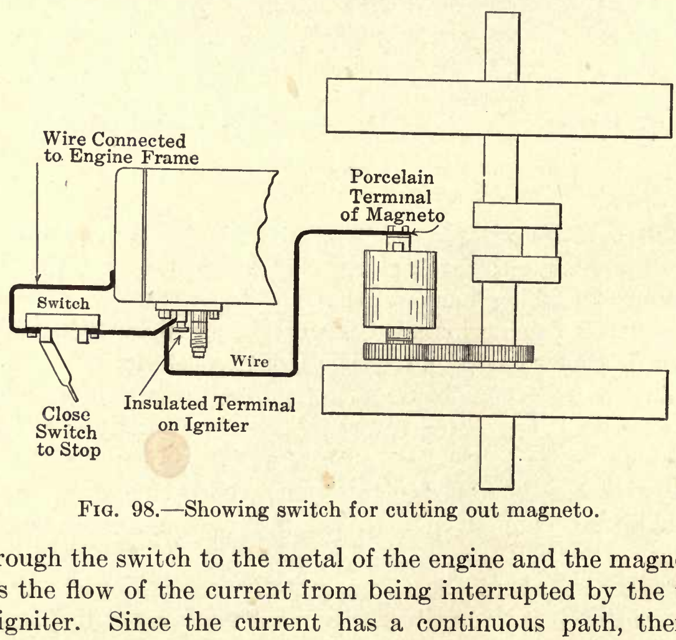


FIG. 98.—Showing switch for cutting out magneto.

path through the switch to the metal of the engine and the magneto, and prevents the flow of the current from being interrupted by the tripping of the igniter. Since the current has a continuous path, there is no induced current when the igniter is tripped.

62. Timing Magneto Ignition.—The tripping of the igniter should occur when the armature is in the position at which the maximum current is generated. By referring again to Figs. 92 and 93, it will be seen that the earliest point at which a satisfactory spark can be obtained is when the armature core is about in the vertical position or a little past this position (position *C* of Fig. 93). Magnetos usually have marks on the shaft and on the bearings indicating the best armature positions for the spark. Figure 99 shows the timing marks for a Sumter magneto, with a notched disk *N* on the shaft and two marks *L* and *R* on the end plate. The following are the directions for setting the magneto: "For *fixed* ignition, turn the engine in the direction in which it runs until the igniter snaps. Do not turn past this point. Observe the setting disk on the magneto shaft, and so mesh the magneto driving gear with the gear on the engine that either small notch *N* is exactly in line with the mark *R* on the end plate if rotation is right-hand, or *L* if rotation is left-hand, looking at the magneto from the gear end."

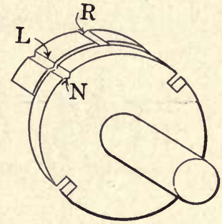


Fig. 99.—Timing marks on Sumter magneto.

It will be seen that this places the armature about 10° to 15° past the vertical or 90° position when the igniter snaps. This produces the spark near the time of greatest current, but as will be seen from Fig. 92, would hardly afford any considerable spark advance on a magneto giving a current wave such as shown there. There is, however, a considerable angle after this position is passed in which a suitable sparking current can be obtained. For a *variable* ignition, where the range is not excessive, the preceding directions can be followed, setting the armature with the spark lever in the starting position. Where a considerable advance is required for the running position, it may be desirable to set the magneto with the igniter or timing lever set in the running position or between the two positions.

When the magneto is properly timed, the gears should be absolutely secured against slipping, and the gears should be meshed so that there is but a very small amount of play. In checking the timing on old engines, the igniter should first be checked with the piston position, as it may have got out of time through wear. After the igniter has been properly adjusted, the magneto timing may be checked with the igniter setting.

Igniters should be adjusted so that the points remain closed as long as possible and open only to make the spark. This gives the magneto time to build up and produce its maximum current.

Figure 100 shows a patented timing arrangement for the igniter which is controlled by the Bosch Magneto Co. and may be used with their magnetos. This offers a very simple method of varying the time of ignition, the roller being shifted so as to be operated earlier or later by the cam. The directions for timing the Bosch magneto with the igniter call for the armature to be in the vertical position, shown in Fig. 101, when the igniter trips when set for full advance. Again referring to Figs. 92 and 93, it will be seen that this allows a considerable retard of the spark and yet utilizes the maximum current when running at full advance. These directions check in theory with those previously given. The igniter of Fig. 100 is so arranged that the circuit is closed at the igniter points except when the roller drops into the deepest depression of the cam. As soon as the cam starts to raise the tappet the circuit is closed by the spring

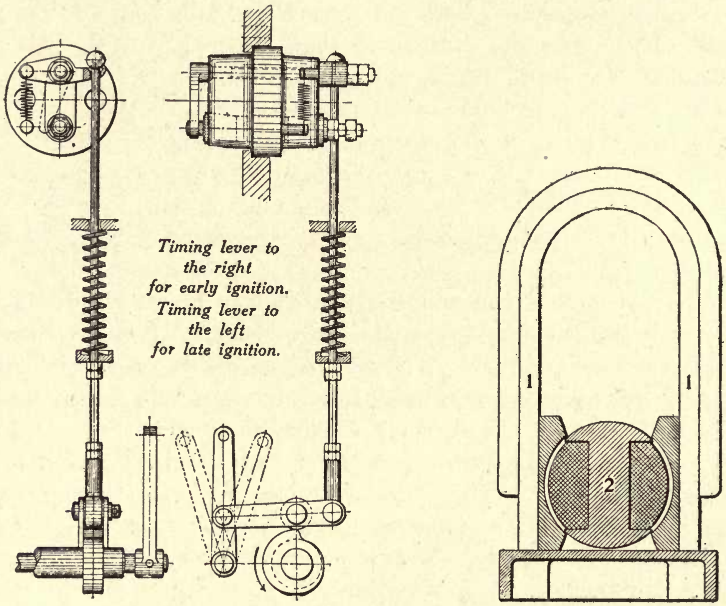


Fig. 100. Fig. 101.
Figs. 100 and 101.—Bosch ignition timing arrangement.

on the igniter. The tappet is then raised farther until the highest point of the cam passes under the roller, when the tappet drops and trips the igniter.

63. Tilting Magnetos for Variable Ignition.—For extreme ranges of ignition timing, the time of the ignition current from a magneto can be changed by tilting the magnets and pole pieces so as to shift the location of the magnetic field with respect to the armature. This is illustrated in Fig. 102, which shows a Sumter magneto of this type. By this means, the same spark can be produced with the igniter in starting or running position and a sparking range of 60° can be provided for. These magnetos are also applicable to two-stroke engines where it is desired to reverse the engine by shifting the spark.

To time this magneto, we first tilt the magnets in the direction in which the magneto is to run. Leaving it in this position, we next set the igniter in full retard position and turn the engine over until the igniter just snaps. The magneto armature should now be set and geared up as shown in Fig. 99, the notch *N* being in line with mark *R* or *L*, according as the rotation is right-hand or left-hand. The engine is now properly timed for starting.

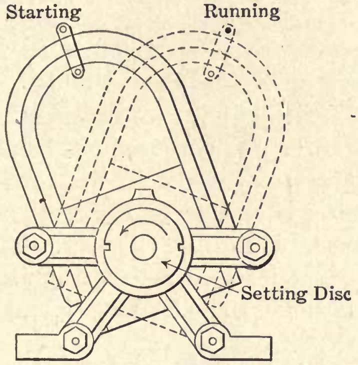


FIG. 102.—Tilting magneto for variable ignition.

Next attach the clamp or shifting lever to the magneto so that the magnets will be moved from starting to running position in unison with the movement of the spark lever from starting to running positions. When the magneto is shifted to extreme running position, the marks that were originally lined up (see Fig. 99) should again line up, showing that the magneto is correctly timed with the magnets in either position.

CHAPTER VI

OSCILLATOR MAGNETOS; INDUCTOR MAGNETOS

64. Oscillator Magnetos.—The oscillator type of magneto is an interesting development of magneto make-and-break ignition. In this type, the magneto armature is not rotated continuously, but is merely rocked a few degrees and then quickly snapped back by powerful springs. As the springs draw the armature back, the current is generated. At the same time, the igniter is opened by the motion of the armature and the spark is thus produced within the cylinder. The magneto is usually mounted on a bracket cast integral with the igniter body, and thus the magneto and igniter become a single unit, operated by a single push-rod.

Sumter.—Figure 103 shows the bottom, top, and side views of the Sumter "Plug-oscillator," the magneto being carried on a bracket which is an extension of the igniter body. The push-rod which ordinarily is used to close and trip the igniter is now used to operate the magneto. This push-rod oscillates a trip lever against the tension of the springs. As the trip lever is moved, it carries with it a dog or crank on the end of the armature shaft, thus turning the armature shaft through an angle of about 30°. The armature is normally held in the vertical position, shown in the third view of Fig. 91. As the trip shaft is rocked, the armature is turned into a position similar to the second position of Fig. 91. This allows the magnetic flux to pass through the armature coil. At the proper time, the push-rod slips off from the trip lever and allows it to recoil quickly under the action of the springs. This draws the armature back into the normal position and permits the magnetic flux to pass across the ends of the armature instead of going through the core and windings. A current is thus generated in the coil. The igniter contacts being closed, and the armature coil being properly connected with them, the current completes its circuit by flowing through the igniter points. Near the end of the recoil, a pin on the trip lever strikes a finger on the igniter shaft, causing the separation of the points and breaking the circuit at the time of maximum current flow. This pin is adjustable so that the break of the igniter points may be adjusted to the armature position.

Accurate.—Figure 104 shows the "Accurate" oscillator with underslung drive. By having the trip shaft separate from the magneto shaft, the magneto bearings are relieved of the thrust of the push-rod.

The arrangement for starting the engine with this magneto is worthy of note. Hanging down under the bracket is a lever which can be latched into the sector of the oscillating bar to cock the magneto for starting. The way this is done is to back the flywheel until the magneto

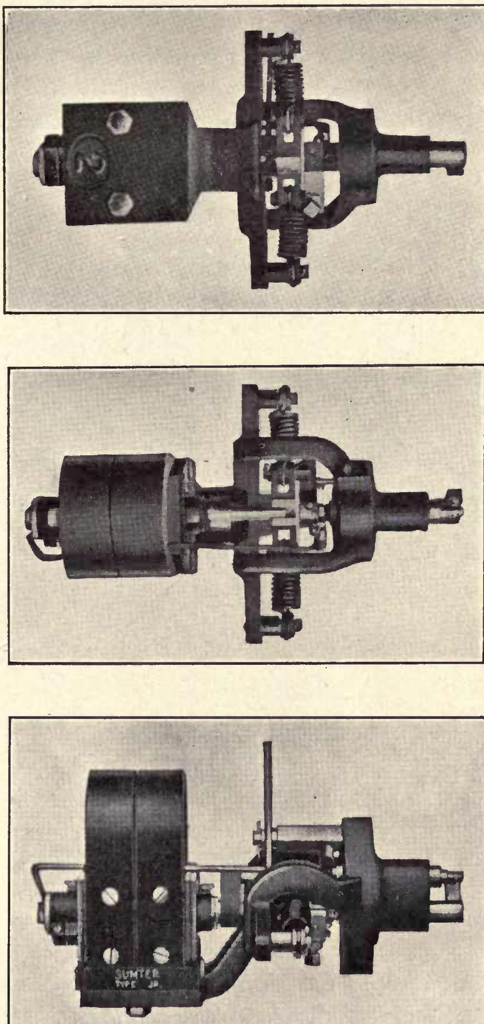


FIG. 103.—Bottom, top, and side views of Sumter plug-oscillator.

has been cocked to nearly its full travel, when this lever can be raised, engaging the notch shown in the figure and thus holding the magneto in the cocked position. The engine is then charged and the flywheel rocked back vigorously against the compression. At the same time, the lever is knocked down by hand, thus releasing the magneto and causing a spark without the necessity of turning the engine over its compression.

By having the magneto separate from the trip mechanism, it is possible to remove the magneto for repairs without disturbing the trip mechanism, and the engine can be operated with a coil and batteries.

Bosch.—An oscillator need not necessarily be mounted as a unit with the igniter. Figure 105 shows an arrangement of a Bosch oscillator by which the magneto may be mounted in a position convenient to the camshaft. The trip lever on the armature is then connected to the

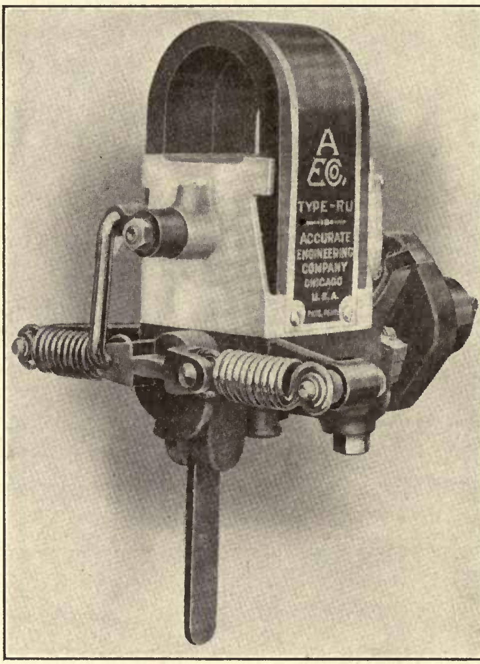


FIG. 104.—"Accurate" oscillator.

igniter so that the latter is tripped by the recoil of the armature. When the armature is in the normal position, as shown, the connecting-rod fork should fail to touch the pin on the movable electrode of the igniter by about 2 mm. or 0.08 in., as indicated by the figure 2. The igniter points are thus held in contact by the spring attached to the movable electrode arm. As the camshaft revolves, the trigger catches the end of the trip lever and rocks the armature through an angle of 30°. This throws the armature into a diagonal position and causes the magnetic flux to pass through the core in going from one pole piece to the other. As the camshaft continues its motion, the trigger passes under the trip lever and releases it. The armature is brought rapidly back by the tension of the springs, and when it reaches the normal position the flux passes across the ends of the armature instead of through the core. On the recoil, the armature will be carried slightly past this position, and as it does so the connecting-rod fork will strike the pin on the movable electrode arm, thus breaking the circuit at the instant of maximum current.

The mark shown on the end of the armature shaft indicates the position of the armature and is used in setting the armature in the vertical position, the trip lever being then fastened to the armature by tightening the nut on the end of the shaft.

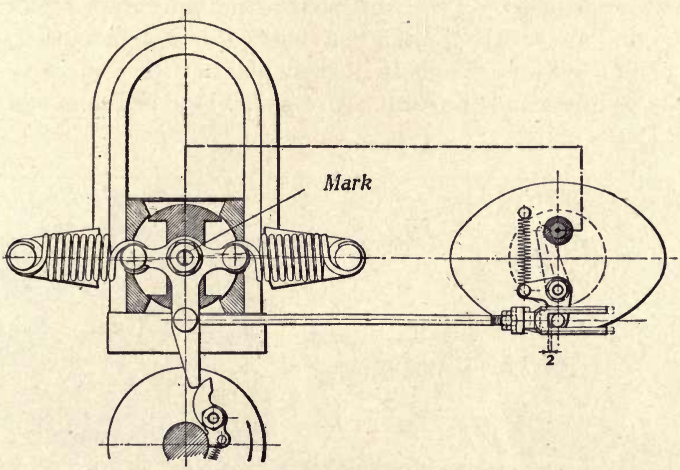


FIG. 105.—Bosch oscillator—trip lever and armature in normal position.

In the use of oscillators, it is the magneto that is tripped instead of the igniter. The igniter is tripped an instant later by the magneto armature on its recoil. It is therefore necessary to have the magneto trip somewhat earlier than when the igniter is tripped directly, as with battery ignition. The International Harvester Co. recommend setting the magneto to trip 15° (of crank motion) earlier than the igniters on battery systems in order to secure the spark at the same time. This will, of course, vary with the speed of the engine.

There are also oscillators which use the inductor type of armature. These will be explained after the principle of the inductor type of magneto has been studied.

65. Principles of Inductor Magnetos.—Since the magneto depends for the generation of electric current on the principle of producing a magnetic field through the core of a coil and then of shifting this field outside of the coil, it is apparent that some other means may be used to produce this change other than the rotation of a shuttle-wound armature. In the inductor magneto, the coil is stationary and the revolving part or inductor which revolves between the pole pieces of the magneto consists merely of the steel shaft carrying laminated iron inductors of suitable shape to produce the desired effect. There are no wires on the revolving parts of the magneto, and all moving wires, sliding contacts, carbon brushes, collector rings, etc., are eliminated from the construction. The inductor magneto is applicable to all forms of ignition service for which magnetos are used, but we will take up at this time only the general principles of action and such applications as have been already explained.

Remy.—Figure 106 shows the inductor and coil of the Remy Model *RD* inductor magneto. Two wing-shaped inductors are mounted on a steel shaft and are revolved on either side of the stationary coil. Figure 107 shows the coil and the shaft in their places with respect to the pole pieces, the magnets and the shaft bearings having been removed. When

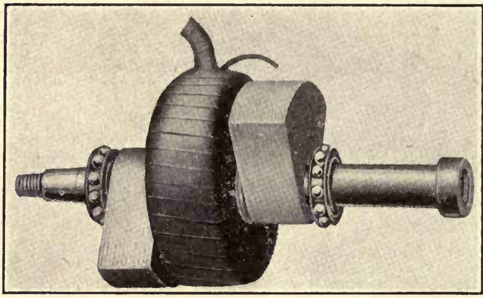


Fig. 106.—Remy inductors and stationary coil.

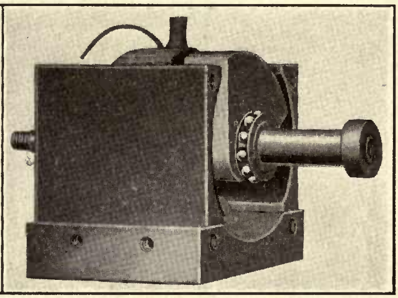


Fig. 107.—Remy inductor shaft and coil assembled in pole pieces and base.

the inductors are in the horizontal position the flux enters one inductor, makes a right-angle turn, passes along the shaft and through the coil to the other inductor and thence to the other pole piece. In this position, we have exactly the same condition as when an armature of a shuttle type is in the horizontal position. When the inductors are revolved to the vertical position the flux passes from one pole piece directly across through the inductors to the other pole piece, and there is no flux through the coil. This change therefore produces a voltage in the coil winding. The outer ends of the inductors are of such length that when they are in the vertical position they offer a direct path from one pole piece to the other, but when they are horizontal, the flux must enter the one inductor, pass through the center of the coil and out through the other inductor.

This magneto will produce two current waves per revolution in the same manner as the shuttle type. The current produced is also an alternating current, as the direction of the flux through the coil is reversed each 180° of revolution of the shaft. Due to the design of the parts, the current wave has an abrupt rise and fall with an almost flat top, making possible a large timing range (35°) at practically the same heat of spark. This magneto is used for jump-spark ignition, the low-tension current generated in the coil being used with a circuit-breaker and a step-up transformer coil. The secondary current from the transformer is led to a distributor on the magneto and there distributed to the different plugs of the engine. The circuit-breaker is mounted on the magneto and operated by a cam on the end of the armature shaft, the cam being mounted so as to break the circuit in proper relation to the position of the armature for maximum current. The details of this ignition system are taken up more fully in a later chapter.

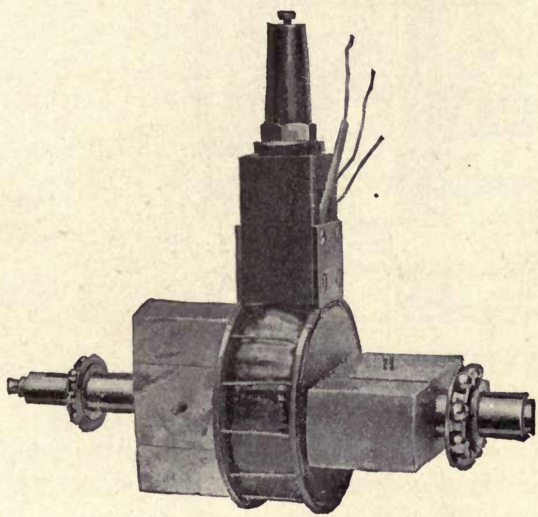


FIG. 108.—K-W rotor and coil.

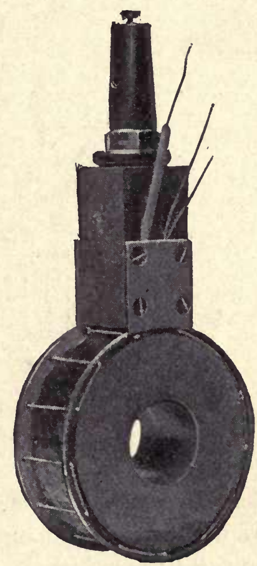


FIG. 109.—K-W coil.

K-W Magneto.—This is another well-known example of the inductor type. Figure 108 shows the inductor shaft and the stationary coil, while Fig. 109 shows the coil alone. In Fig. 110 is shown a section of the magneto with the positions of the coil and inductors shown. The revolving part or "rotor," as it is called, is constructed of fine laminations of the softest Norway iron. These are riveted together and accurately bored out to fit the shaft and are accurately machined as to width and diameter, being mounted on the shaft at exactly right angles to each other. Between these two pieces is the coil shown in Fig. 109. This winding, which is concentric with the rotor shaft, is mounted between the two halves of the rotor but stands absolutely still. In the position shown in Fig. 108, with vertical magnets, the lines of force go straight across through the right-hand part of the rotor, from one pole piece to the other. When the shaft turns 45° from this position, one side of the rotor carries the flux from one pole piece through the center of the winding to the other part of the rotor and to the other pole piece. When the shaft has turned through 90°, the other part of the rotor becomes horizontal and the flux is now carried through it directly across from one pole piece to the other, but on the opposite side of the coil. This magneto thus gives a current wave for each 90° of revolution of the shaft and can give four sparks per revolution. These magnetos are made in both low- and high-tension types, the details of which will be taken up in later chapters.

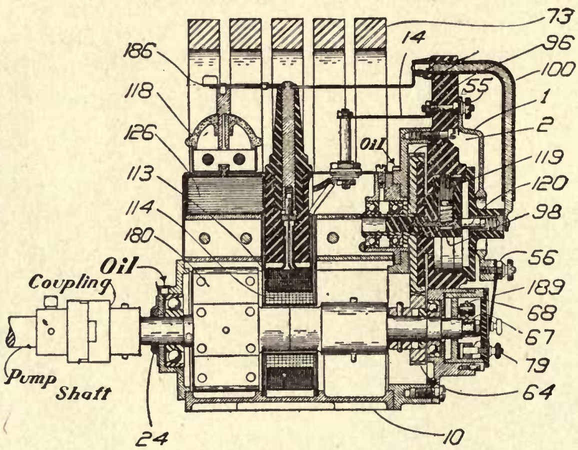


Fig. 110.—Section of K-W magneto.

The one shown here is of the high-tension type, as shown by the double winding of the coil, indicated by the dark and lighter cross-hatchings of the coil in Fig. 110.

Pittsfield.—This magneto involves a very unique feature. Figure 111 shows the principal parts of the magneto, namely: the magnets, the inductors, the coil, and two intermediate poles which we will call the interpoles. The inductors are made of soft-iron laminations carried on bronze heads, not shown. In the position shown in the figure, the flux is carried straight across from one magnet pole piece to the other through the inductors. When the inductors have turned 45° from the position shown, assuming left-hand rotation, the upper inductor will collect the flux from the left-hand pole piece, from which it will pass through this inductor to the upper interpole. It will pass back through this interpole, down through the coil, and thence forward through the lower interpole, through the lower inductor to the other magnet pole. As the inductors rotate 45° more, or 90° from the position shown, the flux is again removed from the coil. At 135° the flux again passes through the coil, but in the opposite direction, and is again removed at 180°. Thus, a current wave is generated for each 90° of revolution or four current waves are generated in one revolution. This magneto is made in the high-tension type, having a double winding in the coil. For automobile use, it has the customary circuit-breaker for the primary winding and the distributor for the secondary current from the high-tension winding. More of these details will be given in the chapter on high-tension magnetos.

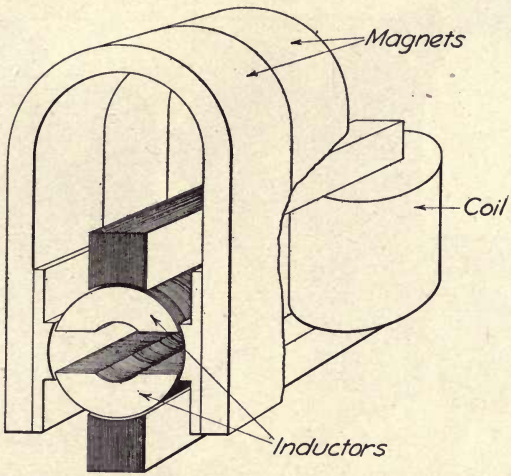


FIG. 111.—Elements of Pittsfield magneto.

66. The Dixie Magneto.—The Dixie is one of the latest developments in the line of magnetos for automobile or other multi-cylinder ignition and, while not exactly of the inductor type in the strictest sense of the word, it is more logically explained under this head than under any other. Incidentally, it is of the high-tension type, although this part of its action will be left to the chapter on high-tension magnetos. It departs from the ordinary inductor in principle in that there is no reversal of the direction of the magnetism through the rotor as it revolves. Figure 112 shows the magnets and the rotor. The latter will be seen to have its axis at right angles to the customary position and to be carried by bearings in the ends of the magnets. The rotor carries two fan-shaped pieces which are always of the same polarity as the poles which they adjoin and are separated by a brass block, which is non-magnetic. In this way, they might be called revolving pole pieces. This rotor revolves between two ends of a field structure, Fig. 113, placed at right angles to the magnets. This consists of two laminated field pieces *F* and *G*, Fig. 115, carrying across their top a laminated core *C* carrying the coil windings *W*. When the rotating pole *N* is opposite *G* the flux flows from the pole N of the magnet to G and through the core C to F, and thence through S to the pole S of the magnet, the flow being as indicated in Fig. 115. When the rotor is in the position of Fig. 116, the flow is stopped through the coil, the poles F and G being neutralized by being subject to equal actions from N and S. In Fig. 117, the position of the rotor has changed to such an extent as to reverse the direc-

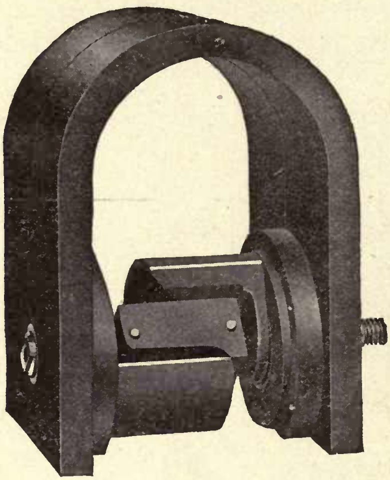


FIG. 112.—Dixie magnets and rotor.

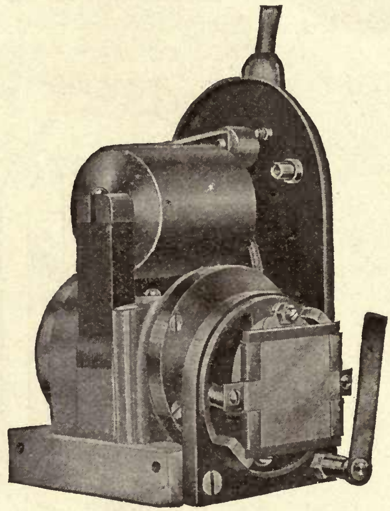
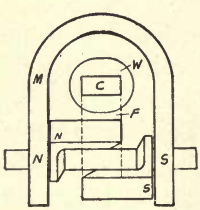
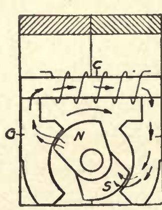
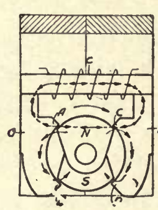


FIG. 113.—Dixie coil and field pieces.







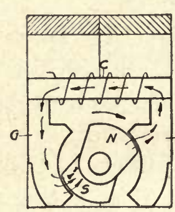


FIG. 114. FIG. 115. FIG. 116. FIG. 117.

FIGS. 114 TO 117.—Showing the principle of the Dixie magneto.

tion of the flux through the coil. The maximum current is generated at approximately the position shown in Fig. 116 and at 180° from that position. This gives two current waves per revolution, the same as in the shuttle-wound magnetos.

67. The Webster Inductor Oscillator.—This oscillator is shown mounted on the bracket as a unit with the make-and-break igniter in Fig. 118. The details of construction are shown in Fig. 119. The magnets are made of two bars placed one over the other. The pole pieces are unusual in form, each being provided with three projections.

They are constructed of a large number of laminations riveted together and attached one to each leg of the horseshoe magnet.

The coils are two in number, one being slipped over the central projection of each pole piece. The inductor, like the pole pieces, is made up of punchings or laminations of iron. These are riveted together and forced on the shaft. The inductor is of a shape somewhat resembling a Maltese cross, there being four poles or projections on it. Figure 120 shows the construction of the inductor.

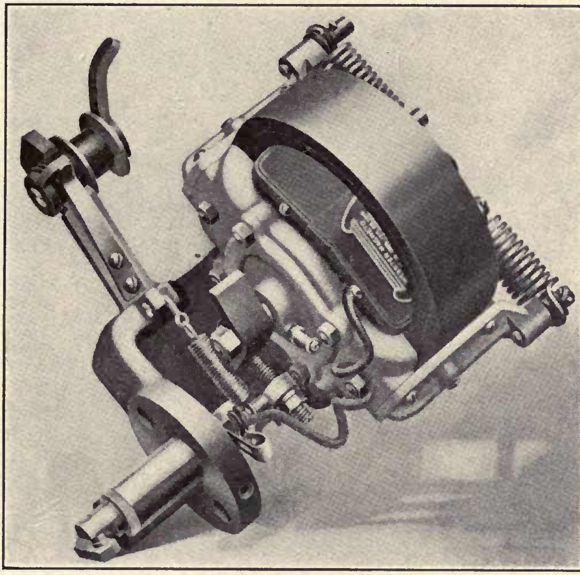


Fig. 118.—Top view of Webster oscillator.

In the normal position of the inductor, two of the poles of the inductor are in line with the outer poles on each pole piece, the flux thus passing outside of the coils. When the inductor is rocked by the push-rod on the engine, it is turned through approximately 45° so that two of the poles of the inductor are horizontal and two are vertical. In this position, the flux passes through the central poles of the pole pieces and through the horizontal poles of the inductor, thus carrying the flux through the inside of the coils. When the magneto is tripped by the push-rod, the springs draw the inductor quickly back into the normal position, thus shifting the flux from the inside to the outside of the coils. This rapid change of flux induces a current in the coils. As the coils are connected in series, we secure at the terminals of the magneto twice the voltage of one coil. At the peak of the wave, the igniter points are separated by the recoil of the push-finger, producing a spark within the cylinder. From this point until the next explosion there is no move-

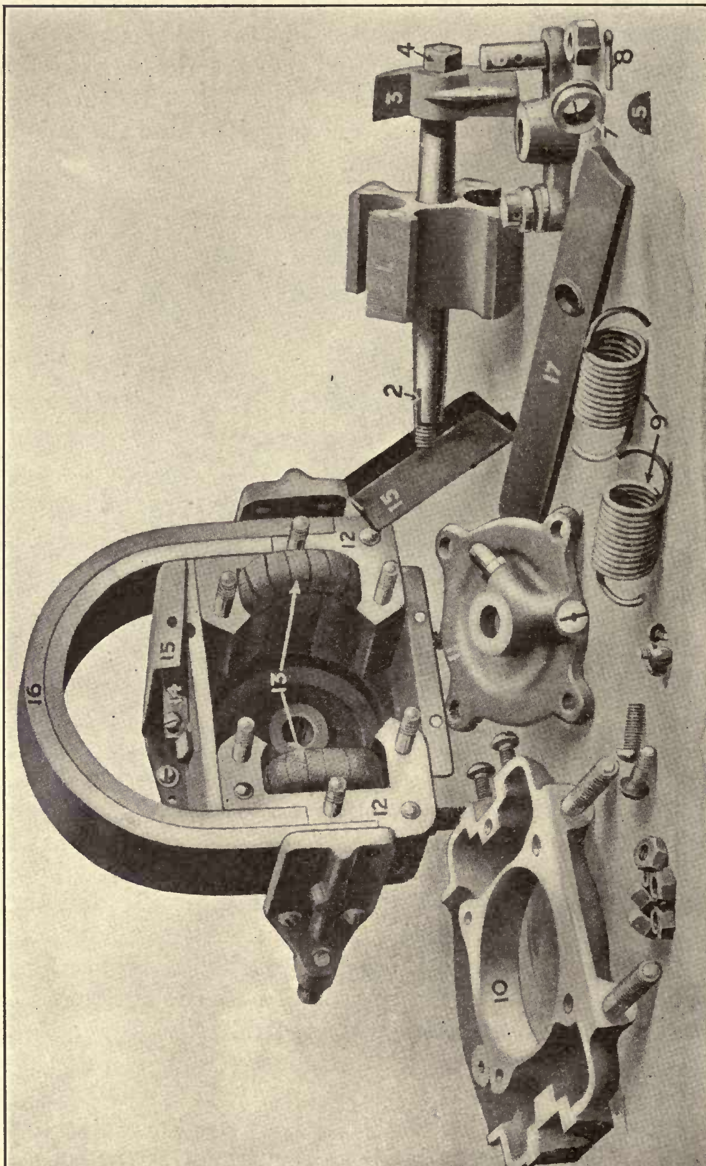


FIG. 119.—Parts of Webster oscillator.

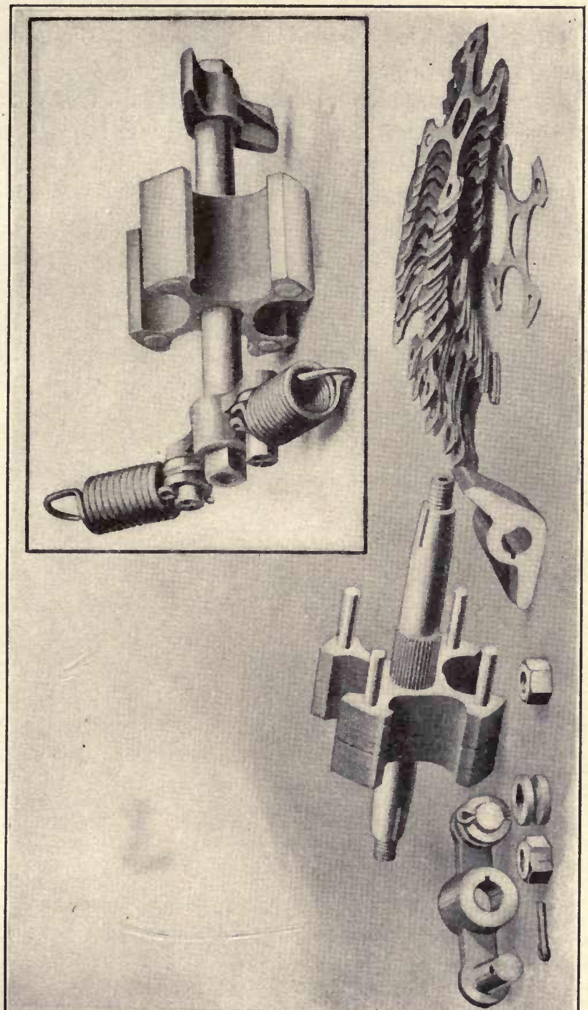


FIG. 120.—Construction of Webster rotor.

ment of the magneto. The push-finger for rocking the inductor and tripping it is shown very clearly in Fig. 118, which shows also the adjustable screw by which the break of the circuit in the igniter is timed to the position of the inductor. The push-rod slides over the roller shown in the upper part of this picture. This roller is mounted on an eccentric so that the roller may be raised or lowered to change the time at which the magneto is tripped.

For starting on compression or from a standstill, a starting lever is supplied by which the inductor may be rocked and tripped entirely by hand.

CHAPTER VII

LOW-TENSION MAGNETOS FOR JUMP-SPARK IGNITION

68. Interrupted Primary Current System.—Since the jump spark is now universally used for automobile ignition, the magnetos for that purpose must provide a high voltage in order to produce the spark. To accomplish this result we find two general types of magnetos; namely, *high-tension* magnetos, or those which produce the high-tension current directly in the armature or magneto winding, and *low-tension* magnetos, which require an induction coil to produce the required voltage. In the latter

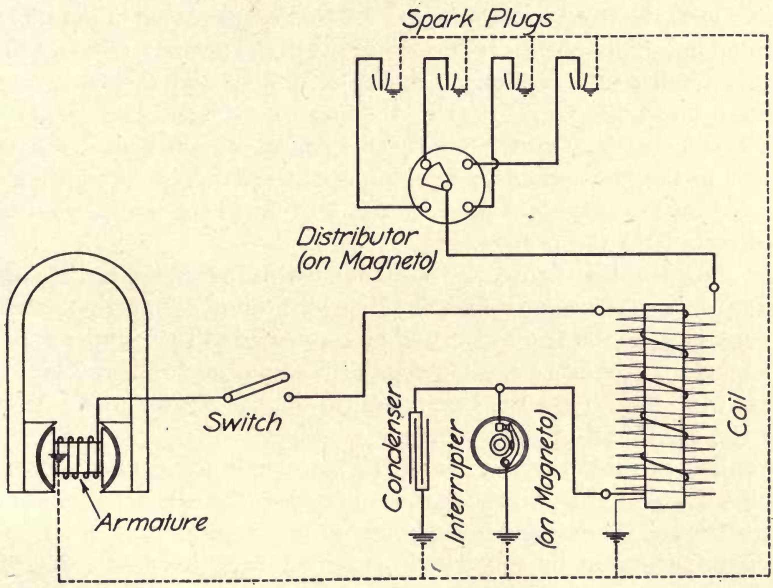


FIG. 121.—Interrupted primary current system.

type we have the magneto as the source of low-tension current. The other parts of the system are quite similar to the non-vibrating coil system described in Chap. III, consisting of an induction coil with a low-tension and a high-tension winding, a distributor for the high-tension current, and a mechanical interrupter for the primary or low-tension current.

Figure 121 shows this system in its simplest form, the illustration representing a magneto with a shuttle-wound armature, although a magneto of the inductor type could be used as well. One end of the armature winding is grounded to the metal of the armature, as is usual in magneto construction. The current is collected from the other end of the winding by a collector ring and brush which have been left out of the figure. The armature current flows through the switch, then through the primary winding of the coil to the interrupter, where the circuit is completed through the ground when the interrupter is closed. The interrupter is here shown separate, but is always mounted on the magneto shaft so that the time of opening the circuit is in proper time with the period of greatest current flow in the armature winding. Assuming the interrupter contacts to be closed, the low-tension current generated in the armature winding therefore flows through the primary winding of the coil and through the interrupter to the ground (on the armature shaft) and back into the armature winding, or in the reverse direction. At the desired time for the spark, which must be during the period of maximum current flow, the primary circuit is broken at the interrupter. This is accomplished by the high point of the cam raising the interrupter lever from its contact with the fixed contact point. A condenser placed in parallel with the interrupter absorbs the induced current in the primary winding caused by this sudden interruption of the current flow and assists in rapidly breaking down the magnetism of the coil core, in the same manner as described for battery systems. By this action, a high-tension current is induced in the fine secondary winding of the coil. The distributor (also mounted on the magneto) receives this current at its central connection and directs it to the proper plug.

As shown in this figure, the secondary winding of the coil is entirely separate from the primary and has its own ground connection. This is not necessary, as the two coils could be connected at their upper ends and the secondary ground be made through the armature to the grounded end of that winding. Then the connection to the distributor would be made from the other end of the secondary winding.

Another possible variation from the figure is in the connections of the switch. Instead of having the switch in series with the armature and its circuit through the coil and interrupter, so that opening the switch breaks the circuit, it might be connected across from the insulated side of the circuit to the ground. In that case the circuit would be through the coil and interrupter when the switch was *open*. When the switch was *closed*, the current would then have a permanent and easy path to the ground and back into the armature, so that practically no current would flow through the coil and interrupter. In this case, closing the switch would "ground" the primary current so that the coil would become inoperative and ignition would cease.

As shown in the figure, the cam has two lobes corresponding to the two current waves produced per revolution in the shuttle type of armature and in some types of inductors. This arrangement is used when the number of cylinders is such that each current wave can be used for the production of a spark. This is the common arrangement for four- and six-cylinder engines. For two-cylinder engines, it is customary to run the magneto at crankshaft speed and to use a single-lobed cam, thus using but one current wave and producing but one spark per revolution.

69. Interrupted Shunt-current System.—In this system, the interrupter is not in series with the circuit through the primary winding of the coil, but is in a "shunt" or cross connection, as shown in Fig. 122. This system, which is quite different from that just described, is the one most used in low-tension magnetos for automobile ignition. The primary current has two possible paths, either through the interrupter, if that is closed, or through the primary winding of the coil. The current natu-

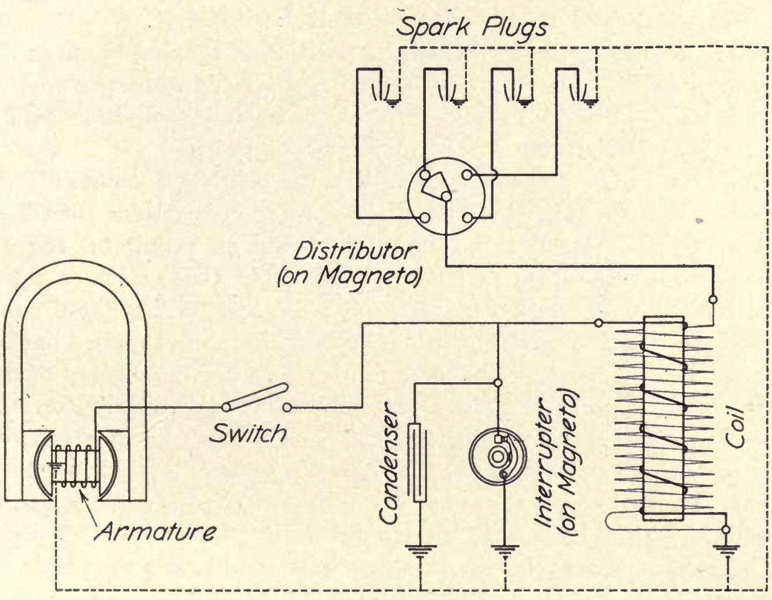


FIG. 122.—Interrupted shunt current system.

rally takes the easier path through the interrupter when that is closed, there being practically no current through the coil at such times. When the magneto armature reaches the desired position for the spark, at some point during the period of maximum current flow, the interrupter is opened. This interruption of the current through the shunt circuit, combined with the action of the condenser, produces an induced current in the armature circuit, and this, having no other path, is shot through the primary winding of the coil. This sudden current through the primary winding induces a powerful momentary voltage in the secondary winding, which voltage is used for the production of the spark, the action of the distributor being as before described.

It will be seen that the spark in this type of magneto is produced by the building up of the magnetic field of the coil instead of by the breaking down of the field, as in the systems previously described. For this reason, the coil is sometimes called a transformer coil because of the nearer resemblance of the action to that of the ordinary transformer. An induced voltage is created in the secondary of any coil when the magnetic field is built up as well as when it is broken down. In battery ignition systems, however, the action of building up is comparatively slow and the induced current is therefore not of sufficient voltage to be used. In this magneto, the coil winding of the armature, coupled with a condenser of proper capacity, produces on the break of the shunt circuit through the interrupter an impulse of current of sufficient power to overcome quickly the inductive opposition of the coil winding and to build up the coil so quickly as to give the desired voltage in the secondary winding.

After the armature has passed the position of maximum current, the interrupter is closed and the armature again has the easy shunt path through which to build up its current as the armature again rotates into the position of maximum current.

As shown in the diagram of Fig. 122, the coil has a common ground connection for the two windings, making three connections for the coil. Most often, the switch and coil are mounted as a unit on the dash. The collector brush on the magneto is connected to the switch on the coil. There is then a connection from the coil back to the insulated contact point on the interrupter. The ground connection is also carried back to a grounded binding post on the magneto frame. The secondary terminal of the coil is connected to the central post on the distributor. This makes four connections when the switch is on the coil, although there are really only three coil connections. When a battery is used for starting purposes, another connection is added to the switch, and sometimes two if the one side of the battery is not grounded directly.

The condenser may be placed either in the coil box or may be built in the magneto.

The switch may be placed in series with the connection from the armature to the coil and interrupter, as shown in the figure, or it may be arranged to permanently ground the armature current so as to short-circuit the current from the coil and interrupter, thus rendering them inoperative. In this latter connection, closing the switch cuts off the ignition current while opening it causes the production of the sparks.

A safety spark gap is also provided, either at the coil or at the magneto.

70. Dual Ignition Systems.—The majority of the low-tension magnetos of the type just described are provided with an arrangement for using battery current for starting purposes, at the time when the magneto current is small due to the low rotative speeds. The batteries can also be used for continuous running in cases of emergency, although the life of the batteries in this case is usually short because of the long contact at the interrupter, which wastes the battery current. The connections at the switch are usually so made that when battery current is used the interrupter is in series between the battery and the coil; then the spark is induced by the interruption of the battery current through the coil. In some of the dual systems, the switch is provided with a push button operating a vibrator or interrupter in the battery circuit, so that a spark can be produced without turning the engine. This enables the operator to start the engine "on the spark" if there is an explosive charge in the cylinder.

71. Connecticut Magneto.—Figure 123 shows a Connecticut magneto partially disassembled to show its construction. This magneto has a shuttle-wound armature revolving between the poles of permanent magnets and generates an alternating current with two impulses per revolu-

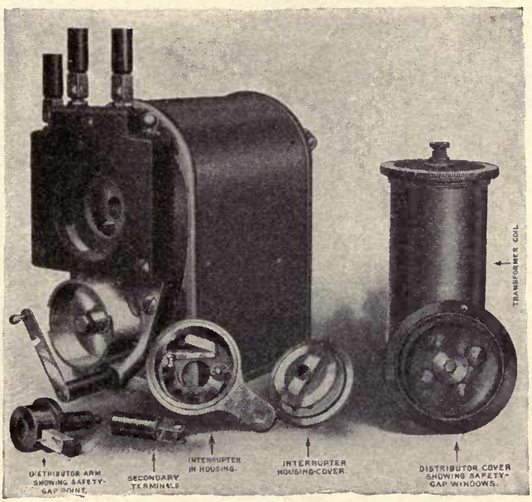


Fig. 123.—Connecticut magneto partially assembled.

tion of the armature. The wiring of this magneto is greatly simplified by having the coil built into the magneto. In the figure the coil is shown removed at the right. When in place it rests in a horizontal position immediately back of the distributor, it being slid and screwed into place from the opposite side of the magneto. Two connections of the coil are automatically made. The secondary connection to the distributor is made when the coil is put into place, as is also the grounded connection for both windings. The insulated end of the armature winding leads through the shaft to the screw head shown in the figure on the end of the shaft. From this screw the current is collected by the brush shown in the center of the interrupter-housing cover; thence it is led to the contact ring, also visible on the view of the cover. A spring on the insulated contact of the interrupter receives the current from this ring.

Independent System.—In the "independent" system, that is, when the magneto is used at all times without a battery, there is only one wire from the magneto to the switch. This wire connects the collector brush in the center of the interrupter cover to one pole of a two-point switch. The other pole of the switch is grounded to some point on the engine or magneto frame. When the switch is closed, the armature current is grounded, thus giving the current a short-circuit and rendering the magneto inoperative.

Dual System.—When the dual magneto is used, there are six connections to be made at the switch, three of them connecting to the magneto, one to the ground, and two to the battery. There are two binding posts

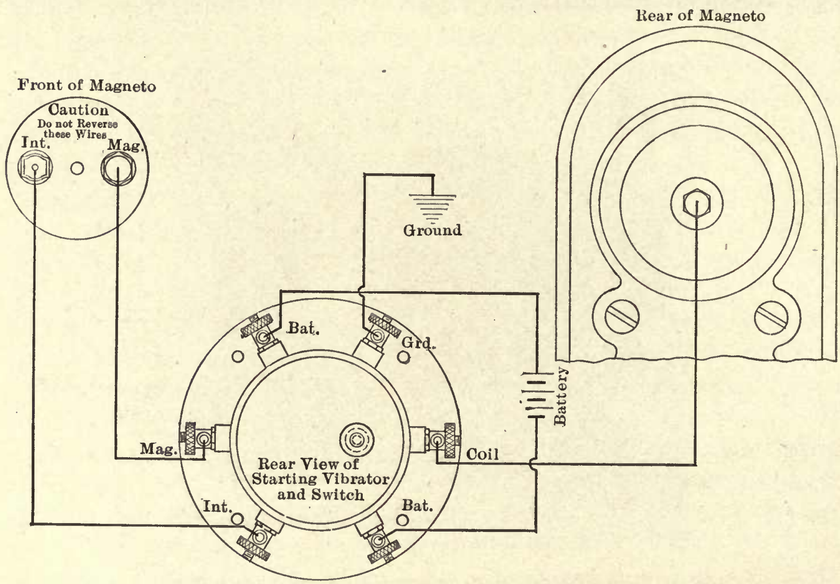


FIG. 124.—Wiring of Connecticut dual magneto and switch.

on the interrupter cover to be connected to the switch, one of them from the brush which collects the armature current. This is marked "Mag." The other connects to the interrupter contact and is marked "Int." The connection of these two to the switch, instead of having the direct connection as in the independent system, enables the interrupter to be used for either magneto or battery current according to the position of the switch. It is important that these connections be made properly and not interchanged, as a wrong connection would allow battery current to flow through the armature and would demagnetize the magnets by setting up an opposing magnetizing force in the armature.

The diagram of Fig. 124 shows the connections for the Connecticut Dual system.

On the front of the switch is a push button connected with a vibrator. When the switch is in battery position, pushing this button causes the battery and coil to act like a vibrator coil system and produces a shower of sparks which will start the engine if there is an explosive charge in the cylinder.

The magneto shaft is provided with two projections to operate the interrupter in phase with the two waves of current. The interrupter housing may be swung through a limited angle to advance or retard the spark within the limits of the current wave. Since there are two sparks per revolution of the armature, the speed of rotation is as follows for different engines:

For four-cylinder two-stroke engines (cranks at 90°), the magneto should be driven at twice crankshaft speed.

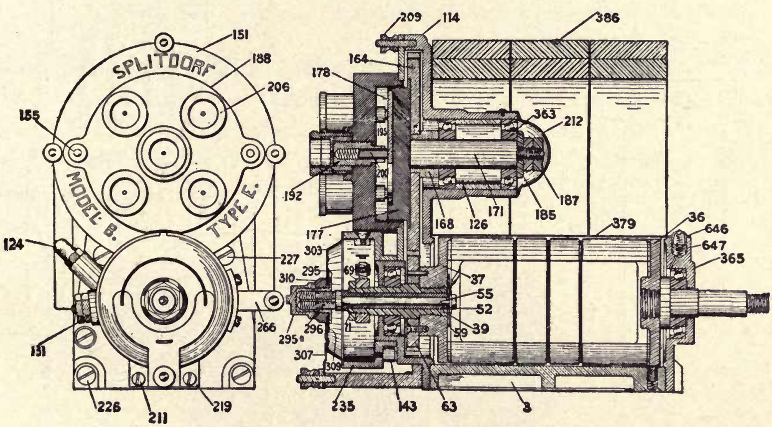


Fig. 125.—Splitdorf magneto.

For four-cylinder four-stroke engines (cranks at 180°), the magneto should be driven at engine speed.

For six-cylinder two-stroke engines (cranks at 60°), the magneto should be driven at three times engine speed.

For six-cylinder four-stroke engines (cranks at 120°), the magneto should be driven at one and one-half times the engine speed.

72. Splitdorf Magneto.—A sectional view of this magneto is shown in Fig. 125. The armature is of the shuttle-wound type, the insulated end of the winding being connected to the insulated bolt, 55, by which the current is conducted to the collecting brush in the center of the interrupter housing. The two-to-one gears for driving the distributor are clearly shown at 63 and 164, this being a magneto for a four-cylinder engine. If it had been a six-cylinder magneto, the gears would have had a three-to-one ratio. The distributor consists of a plate, 177, of insulating material carrying a brass plate, 178, which receives the high-tension current from the central post, 192, and distributes it to the carbon brushes for the different plugs, one of which is shown at 195. Both the armature and distributor are carried on two sets of annular ball bearings. The interrupter is provided with an arm, 266, for swinging the interrupter to shift the spark within the range of the current wave.

Splitdorf Dual System.—The wiring diagram for the dual system is shown in Fig. 126. This is for the Model *T* magneto, the chief difference from Model *B* shown in Fig. 125 being in the vertical connections to the plugs.

The connections to and method of operation of the switch are of especial interest. The figure shows the position of the switch when thrown to

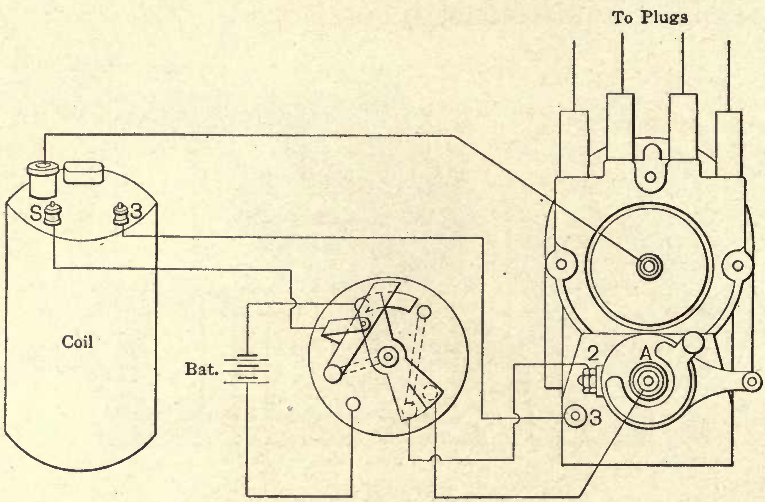


FIG. 126.—Wiring diagram of Splitdorf Model T magneto with five point switch.

"Magneto" side. The armature current is led from the collecting brush *A* to the switch, where the blade connects it both to the coil at *S* and to the interrupter at 2. The other side of the coil is grounded to the magneto frame at 3. This places the coil and interrupter in parallel and gives an interrupted shunt-current system as explained in Art. 69.

When the switch is thrown to "Battery" position, the blade in the figure is moved in a clockwise direction and connects one side of the battery to the coil at *S* and the other side to the interrupter at 2. This places the battery, interrupter, and coil in series and causes the coil to build up when the interrupter is closed and gives the spark in the secondary when the interrupter opens. The connection 3–3 from the coil to the magneto is a permanent ground connection for both primary and secondary windings. The interrupter connects post 2 to the ground when the interrupter is closed.

73. Remy Model P Magneto.—The Remy magneto is made in both inductor and shuttle-wound armature types. The Model *P* is of the shuttle-wound armature type and operates on the interrupted shunt-current principle of Art. 69. The exterior of the magneto with interrupter or circuit-breaker removed is shown in Fig. 128 and will be seen to be of

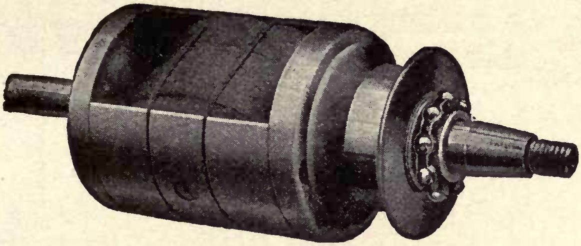


FIG. 127.—Armature of Remy Model P magneto.

conventional form. The armature is shown separately in Fig. 127. Figure 128 shows the circuit-breaker cam on the end of the armature shaft, while the circuit-breaker arm and stationary contact are shown clearly in the view of that part of the magneto. The external wiring diagram is shown in Fig. 129. The collector ring for taking off the current

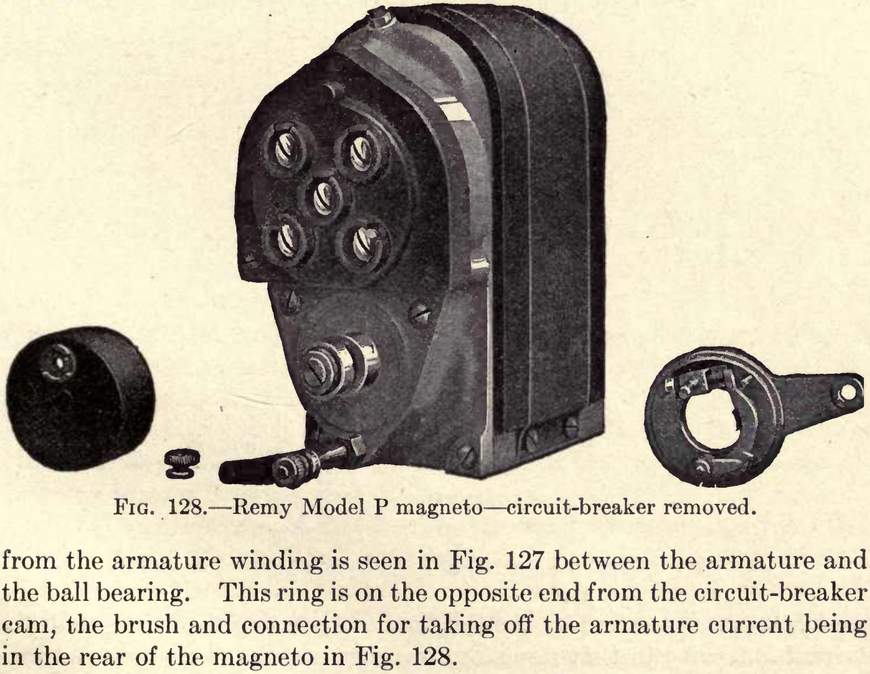


FIG. 128.—Remy Model P magneto—circuit-breaker removed.

from the armature winding is seen in Fig. 127 between the armature and the ball bearing. This ring is on the opposite end from the circuit-breaker cam, the brush and connection for taking off the armature current being in the rear of the magneto in Fig. 128.

In the wiring diagram of Fig. 129 it will be observed that there are two battery connections to the switch and coil, one secondary connection from the coil to the distributor, and three other connections designated by green, red, and yellow wires. The green wire carries the armature current, the red wire is the common ground connection, and the yellow wire is the connection to the insulated post of the circuit-breaker.

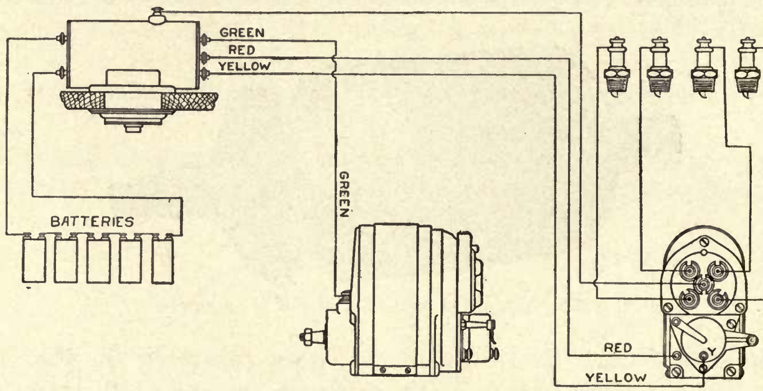


FIG. 129.—External wiring diagram for Remy Model P magneto.

The internal wiring of the primary system is shown in Fig. 130. This diagram is essentially the same as Fig. 122 as far as the magneto circuit is concerned. The switch carries two parallel blades which are shown in

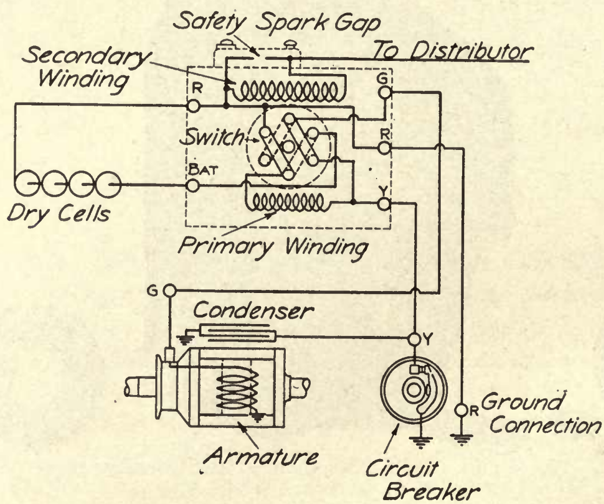


FIG. 130.—Internal wiring diagram for Remy model P magneto.

the "Magneto" position by the full lines. Assuming that the armature current is flowing in that direction, the current from *G* on the magneto is led to the connection *G* on the coil, then through the right-hand switch blade to a point midway between the primary winding and the post *Y* on the coil. *Y* is connected to the circuit-breaker and to the condenser. When the circuit-breaker is closed, the current flows through the switch and circuit-breaker to the ground and back into the armature. When the circuit-breaker opens, the current loses this path and is thrown through the primary winding, then to the point at the bottom of the switch, and through the left-hand blade to the common ground wire *R*. The path just described assumes current flow in one direction. When the armature has turned 180°, the current flow is in the opposite direction from that described.

When the switch is thrown to "Battery" position, the blades assume the position shown in the dotted lines. The armature current now has no path, the circuit from *G* being open as shown by the dotted position of the left-hand blade of the switch. Assuming the flow of battery current

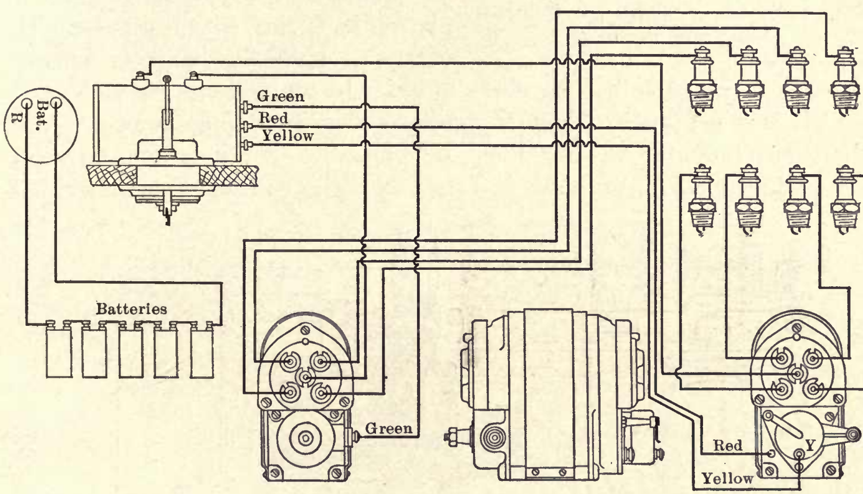


FIG. 131.—Remy two-point ignition system.

from left to right, the current enters the "Bat" connection on the coil, flows around through the right-hand blade of the switch, through the primary winding from left to right, and to post *Y*. From here it goes to the circuit-breaker and to the ground, returning to the battery through the ground wire *R*. The circuit is broken by the circuit-breaker at the desired instant for the spark.

This switch arrangement enables the coil, circuit-breaker, and condenser to operate with either source of current to produce the spark on the break of the circuit-breaker; yet the spark is produced with the battery by the destruction of the magnetic field of the coil, while with the armature current it is produced when the current is thrown into the coil.

Two-Point Ignition System.—For heavy duty service, such as on traction engines, this magneto is made to produce two sparks simultaneously, by means of two distributors and two plugs in each cylinder. Figure 131 shows the external wiring diagram for one of these magnetos and shows the two distributors, one on each end of the magneto. The primary system is the same as that just described and may use either battery current or magneto current. The chief difference is that one side of the secondary winding is not grounded. One end of the secondary coil is led to one distributor and the other end to the other distributor. The only grounded part of the secondary circuit is that between the two plugs in the cylinder. With the distributors directing the current to the two plugs in one cylinder, the two plugs are thus placed in series with the secondary winding, and the ignition current must leap the gaps in both plugs in order to complete its circuit.

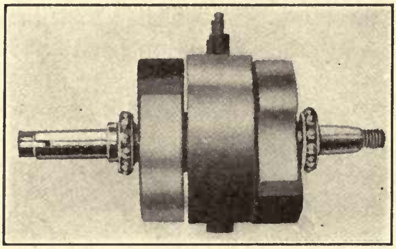


FIG. 132.—Remy type RL inductor shaft and winding.

74. Remy Inductor Type Magnetos.—The fundamental principle of the Remy inductor was explained in Chap. VI. The inductor and winding of the type *RL* are shown in Fig. 132. The coil winding is held stationary between the pole pieces of the magneto, while the direction of the magnetic flux through it is rapidly reversed by the rotation of the inductor shaft. Each inductor has a fan-shaped arm on one side, the other side being balanced by a similar piece of non-magnetic material. Figure 133 shows an end view and a section of one of these magnetos, type *RD*,

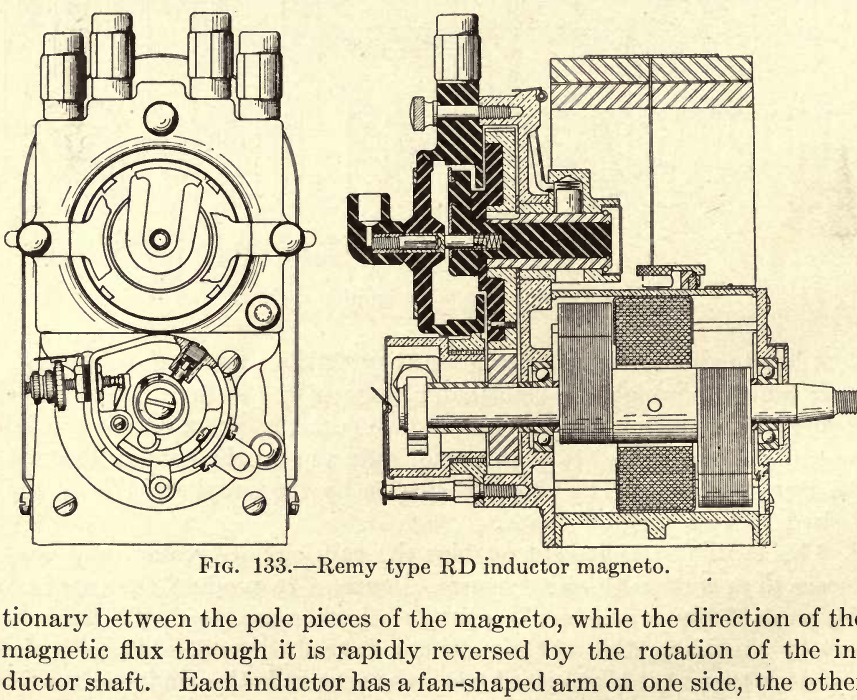


FIG. 133.—Remy type RD inductor magneto.

without balance weights. The action of the distributor is clearly shown in this figure. The arm does not rub against the connections to the different plugs, but has a very small gap through which the secondary current must jump. This overcomes any objections to rubbing contacts.

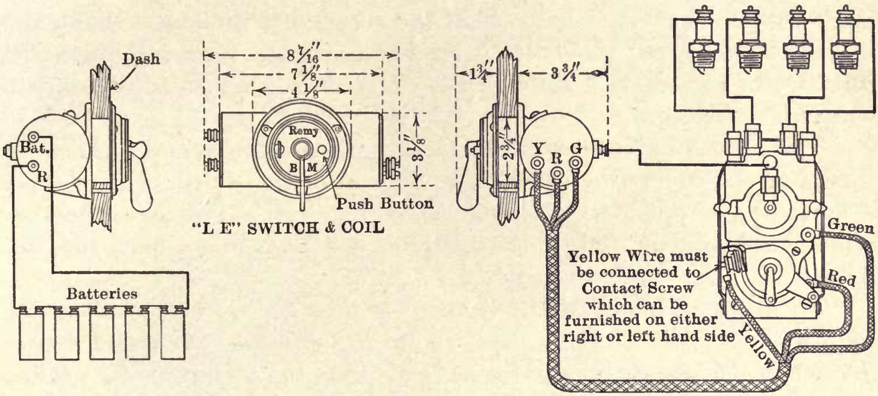


Fig. 134.—External wiring of Remy RL magneto with unit coil and switch.

The external wiring diagram with switch and coil combined in one unit is shown in Fig. 134, while that for the separate coil and switch units is shown in Fig. 135. There are three primary connections from the

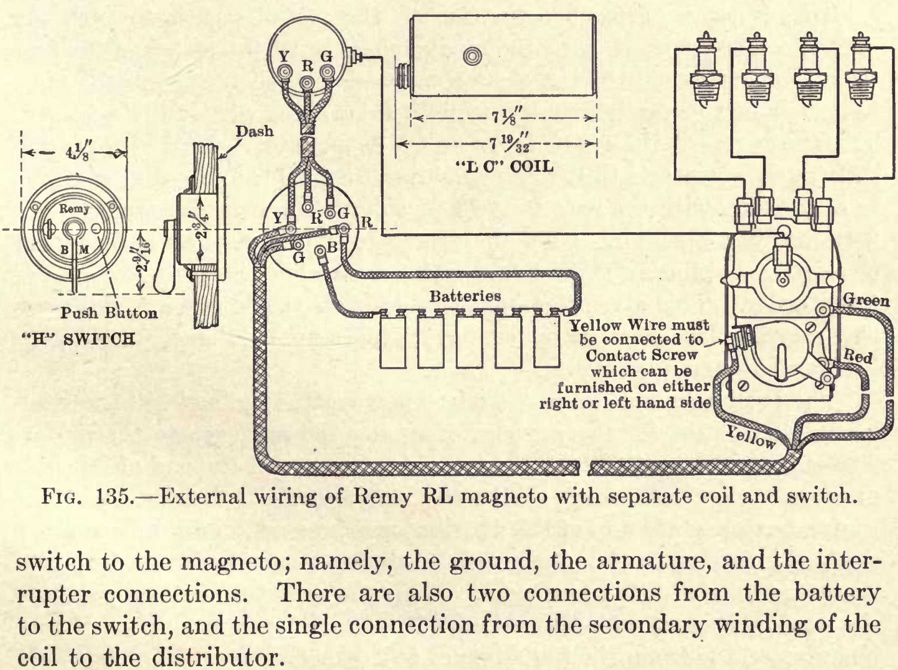


Fig. 135.—External wiring of Remy RL magneto with separate coil and switch.

switch to the magneto; namely, the ground, the armature, and the interrupter connections. There are also two connections from the battery to the switch, and the single connection from the secondary winding of the coil to the distributor.

The magneto operates on the interrupted primary current system of Art. 68. The stationary winding is directly connected through the circuit-breaker with the primary winding of the coil. The circuit is mechanically broken when the current has reached a high value. On the interruption of the magneto current through the primary winding, a high-tension current is induced in the secondary winding. When the batteries are used, the battery current is simply turned through the primary of the coil and through the circuit-breaker, instead of magneto current.

This inductor gives two current waves per revolution and is therefore timed to the engine the same as a magneto of the shuttle-wound type. The timing of the spark is accomplished by shifting the circuit-breaker around the inductor shaft in the usual manner. There is a spark range of about 35°.

75. Magneto Installation.—A magneto should always be installed on a bronze, brass, or aluminum base, as an iron or steel base would deflect some of the magnetic lines of the magnets from the armature and weaken the action of the magneto. The magneto may be fastened down with machine screws, or with a metal strap over the top of the magnets. The ratio of the speed of the armature to the speed of the engine differs with the number of current waves generated per revolution of the armature. The majority of magnetos give two current waves. For these, the speed ratio is given at the end of Art. 71.

To adjust the armature position to the piston positions, with the magneto disconnected, turn the engine shaft until the piston of the first cylinder has reached the top of its compression stroke. This is the position at which the spark should usually take place when fully retarded. Therefore, retard the spark lever as far as possible. Now remove the distributor cover and turn the magneto shaft until the distributor arm is in connection with the wire to the first cylinder and the interrupter contacts are just opening. Hold the armature in this position and connect the drive coupling. Then connect the remaining cables in the proper firing order. This gives the maximum possible spark advance and gives the retarded spark on dead center. This may be slightly altered to suit individual requirements.

The Remy *P* magneto has a device known as the timing button located in the distributor for the purpose of timing the magneto to the motor. The engine is set with No. 1 piston on dead center at the end of its compression stroke, as before. With the magneto shaft disconnected, the timing button at the top of the distributor is pressed in and the armature shaft is turned until the plunger of the timing button is felt to drop into the recess in the distributor gear. With the armature in this position, the driving connection is completed. The spark lever connection should be adjusted to obtain the full advance and retard.

76. The Ford Magneto.—This magneto may be classed as a high-frequency, alternating-current magneto. It serves merely as the source of primary current for an ordinary vibrating-coil type of ignition system.

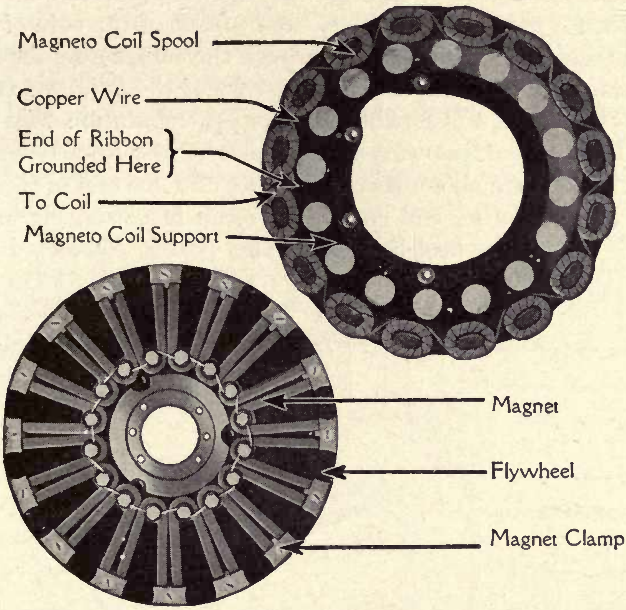


Fig. 136.

The construction of the magneto is shown in Fig. 136, while the wiring diagram is shown in Fig. 137.

The stationary and revolving elements are interchanged from the

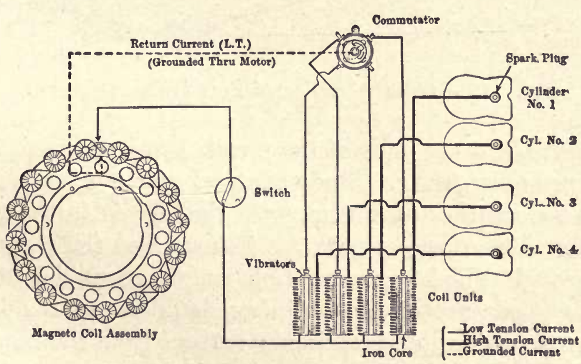


Fig. 137.—Internal wiring diagram of Ford ignition system.

customary relation. The armature coils are stationary and the magnets revolve. The armature consists of 16 coils which are attached to a stationary supporting disc in the flywheel housing. An equal number of permanent magnets of the horseshoe type are secured to a non-magnetic ring attached to the flywheel. The magnets revolve with the flywheel at a distance of $\frac{1}{32}$ in. from the coils. The North poles of two adjacent magnets are fastened together, and likewise the next pair of poles are South poles. When a pair of North poles are in front of the core of one of the coils, the magnetic flux will flow in through the core, across the supporting frame of the coils, and out through the core of the adjacent coils to the South poles. When the flywheel makes $\frac{1}{16}$ revolution this flow is reversed. Thus 16 current waves are generated per revolution of the flywheel. The coils are all connected in series and one end of the winding is grounded and the other end connected to an insulated binding post on the outside of the flywheel housing. This post is connected to all four

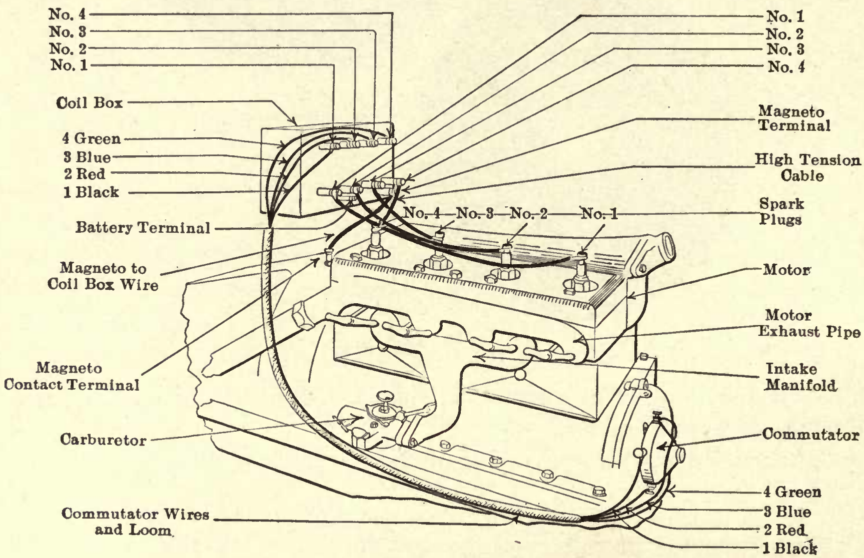


FIG. 138.—External wiring of Ford ignition system.

induction coils, the other ends of these coils being connected to the four posts of an ordinary timer. Since one end of the magneto winding is grounded and since the timer completes the circuit to the ground from each induction coil in proper order, it follows that the magneto current will pass through whichever induction coil is grounded at the timer. The induction coils are of the ordinary double-wound induction type with vibrators to interrupt the primary current from the magneto. The secondary of each coil has a direct connection to the plug of one of the cylinders with a grounded return. Figure 138 shows the complete system installed on the engine.

This magneto is quite unlike those previously described in that the current waves are of high frequency and are not all used for ignition.

The alternations of the magneto current are frequent enough to cause only a slight variation in the instant of ignition as affected by the periods of no current. The length of contact in the timer is sufficient to overlap from one current wave to the next. In case the magneto is in a position where no current is generated when the timer first makes contact, there will be a lag of a very few degrees in the spark until the magneto has turned into a position where it will generate sufficient current to operate the coil. Due to the shape of the current waves, the greatest possible lag due to this cause is probably not more than 5°.

Magnetos of the two-pole type can also be used as high-frequency sources of current by having them driven at high speeds so as to produce the frequent alternations. This is most often done by having them belt- or friction-driven from the flywheels of the engine. Some of these have been used for stationary engine ignition and occasionally for automobile ignition, but they have been superseded by the alternators driven in a fixed timing relation to the engine shaft.

CHAPTER VIII

HIGH-TENSION MAGNETOS

77. Principles of High-tension Magnetos.—In the foregoing chapters we have considered low-tension magnetos, in which the low-tension current produced in the single winding of the magneto is stepped up to a voltage of higher value by means of a transformer coil, sometimes mounted away from the magneto and sometimes placed under the arch of the magnets. In these magnetos, the condenser also has frequently been a separate piece of apparatus, sometimes located under the arch of the magnets but more often included in the same casing as the transformer coil. These magnetos are known, strictly, as low-tension magnetos.

Under the name of high-tension magnetos are included those in which the primary and secondary windings are both wound on the same core. In the armature type, both primary and secondary windings are wound on the armature, and a current of high voltage is produced directly in the secondary winding of the armature without the use of a separate transformer. In the inductor type, the stationary coil between the pole pieces has both primary and secondary windings. The Dixie and Pittsfield magnetos are also placed in this class, although the windings in these magnetos are not located in the revolving parts of the machine.

In the rotating armature type of high-tension magneto, the armature carries two windings, a primary of comparatively coarse wire and of few turns, and a secondary of many turns of much finer wire. The condenser is also included in the rotating element of these machines, producing as a whole a remarkably compact and efficient machine.

The interrupter or circuit-breaker is usually mounted on the armature shaft and revolves with it, the cam being on the inside of the interrupter housing, thus reversing the usual arrangement of the low-tension magneto, which has the cam on the armature shaft and the interrupter in the housing. By having the interrupter, condenser, and primary winding all on the armature, the entire primary circuit is thus contained in the armature. The secondary or high-tension current is collected from the armature by a collector ring and a brush in the same manner that the primary current is collected on a low-tension magneto.

The interrupter acts as a timer by breaking the circuit of the primary winding of the armature. When the flow of current through the primary winding is thus interrupted, a current of high voltage is induced in the secondary winding of the armature in the same manner as in an ordinary spark coil, but owing to the rotation of both primary and secondary windings of the armature, there is a peculiar combination of inductive and generative effects. The induced current produced by the interruption of the primary circuit lasts a very short interval of time and, acting alone, would produce but a single flash at the spark plug. However, owing to the revolving of the secondary winding in the magnetic field, a more continuous current of not so high a voltage is generated. This generated current alone is not sufficient to break down the resistance at the gap in the spark plug, but at the instant the primary circuit is interrupted, the induced current is sufficient to break down this resistance and then the somewhat lower voltage of the generated current is able to cross the gap,

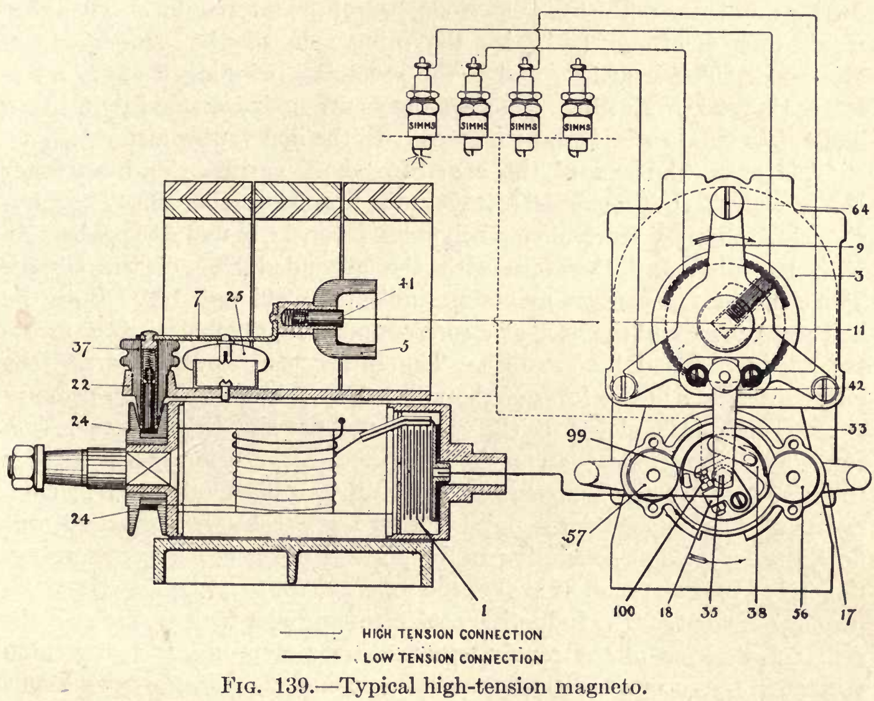


Fig. 139.—Typical high-tension magneto.

thus producing not an instantaneous flash but a flame which lasts for a considerable period of armature rotation.

During the period of rotation when the magnetic field is passing through the armature core, the interrupter points are closed, thus giving the primary current a closed (short) circuit. As the armature revolves so as to remove the field from the armature core, a voltage is generated in each winding proportional to the numbers of turns in the two windings. Since the primary circuit is closed, a considerable current will flow through it. At approximately the instant when the generated voltage would be greatest, the interrupter breaks the primary circuit and thus adds the inductive action to the generative action and produces an exceedingly high voltage in the secondary winding.

A typical arrangement of a high-tension magneto is shown in Fig. 139, which is a Simms British type SD4 magneto. The armature winding is shown as a single layer, although in reality there are several layers of wire. The heavy lines represent that part of the winding which forms the primary. The windings are arranged so that both the heavy and light lines form the secondary winding, just as in some induction coils the windings are so arranged that the primary is also a part of the secondary. One end of the armature winding is grounded on the armature core. At the other end of the primary a connection leads to one side of the condenser 1 and also to the fixed electrode, 100, of the interrupter. The other interrupter electrode and also the other side of the condenser are grounded. The insulated end of the secondary winding leads to a collector ring, 24, from which the secondary current is collected by a brush and led to the brush, 41, which gives it to the distributor arm, 11.

A disc on the end of the armature shaft carries the interrupter parts. On this but insulated from it is the fixed electrode, 18. The movable electrode, 99, is carried on a bell crank lever, 38, in metallic connection with the disc, and therefore with the grounded side of the circuit. The electrodes or contact points are indicated at 99 and 100. Both the bell crank lever and the fixed electrode support, 18, revolve with the armature, being carried by the disc. The interrupter housing carries the interrupter cam in the form of the two rollers, 56 and 57. The primary circuit is normally closed by the contact points being held together by a spring. This permits the current generated in the primary winding by the revolution of the armature to build up to a high value. When the armature has reached some point during the period of greatest current flow, the exact point depending on the position of the interrupter housing, the end of the bell crank 38 strikes the roller, 56 (or 57), and interrupts the primary current. The inductive action thus produced supplements the generative action of the revolving armature and produces a very high voltage in the secondary winding. This secondary current is taken off at the collector ring, 24, and led to the distributor, where it is directed to one of the plugs.

A safety spark gap through which the secondary current can escape is provided at 25, so that in case the wires to the plugs are disconnected or if for any other reason the secondary current does not have the usual path, the secondary can discharge through this safety spark gap and thus avoid the danger of the high voltage breaking down the insulation and escaping at some other point.

As in the low-tension armature type of magneto, there are two sparks produced per revolution of the armature. The distributor is therefore similar to that found on the low-tension magneto and is driven at similar speeds. The only difference is that the secondary current is received direct from the armature instead of being brought back to the distributor from a transformer coil. For a four-cylinder engine the distributor has four segments and is driven at one-half the speed of the armature. For a six-cylinder engine there are six segments and the distributor arm is driven at one-third the speed of the armature. The relations of magneto speeds to engine speeds are also the same as for the armature type of low-tension magnetos. For a four-cylinder four-stroke engine the armature revolves at crankshaft speed. For a six-cylinder four-stroke engine the armature revolves at one and one-half times crankshaft speed.

The condenser, as in all high-tension armature-type magnetos, is located in one end of the armature. It is connected in parallel with the primary winding and the interrupter circuit. As stated in previous chapters, the purpose of the condenser is to absorb the induced charge in the primary winding and prevent the discharge of this current across the interrupter points. The charge in the condenser immediately surges back into the primary winding in the opposite direction to that of the primary current, thereby causing a more rapid demagnetization of the armature and consequently producing a higher voltage in the secondary winding than would otherwise be obtained.

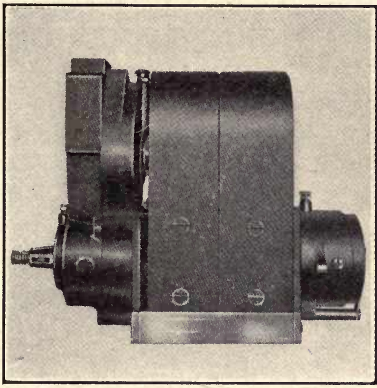


FIG. 140.—The Swiss magneto.

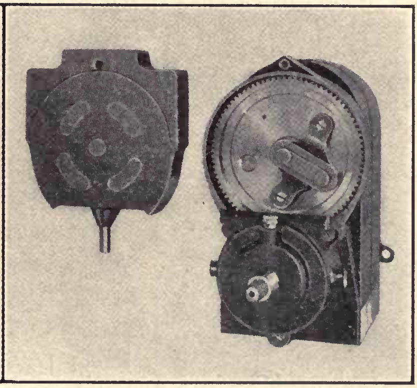


FIG. 141.—Distributor end, the Swiss magneto.

78. The Swiss Magneto.—Figure 140 shows the exterior of the Swiss magneto, which differs from the conventional form in that the distributor is mounted on the opposite end from the interrupter. As the collector ring and brush for collecting the secondary current from the armature winding are on the driving end of the armature, this places the distributor directly above the collector ring and permits of a direct internal connection from the collecting brush to the distributor arm. Figure 141 shows the distributor cap removed. This cap carries the brush, which is shown projecting below the cap. This leads to the central metal pole on the face of the cap. The distributor arm has two brushes, one in contact with this central pole and the other making contact successively with the different segments, which are connected to the spark plugs.

Figure 142 shows the armature of this machine. At the extreme right is shown the interrupter, carried on a plate attached to the armature shaft. The winding, 2, has both primary and secondary windings about a laminated H-shaped armature core. At 3 is shown the insulated con-

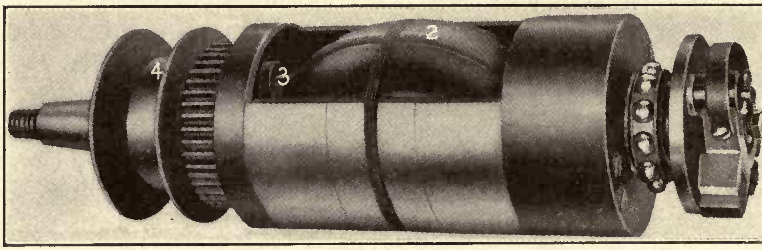


FIG. 142.—The Swiss armature.

nection from the end of the secondary winding to the collector ring, 4. The condenser is placed inside the brass cap at the right end of the armature. At the right of the collector ring, 4, is seen the gear for driving the distributor. The construction of the interrupter is shown in Fig. 143. The part marked *L* is the movable contact lever, this one being for left-hand rotation. The circuit is broken by the fiber block shown in the lower part of this figure striking a projection on the inside of the interrupter housing.

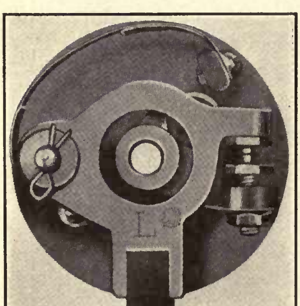


FIG. 143.—Swiss interrupter.

One interesting feature of this magneto is the provision for cutting out the spark in order to stop the engine. The customary method of stopping the ignition on a high-tension magneto is to permanently ground the low-tension or primary current, thus stopping the inductive action when the interrupter contacts separate. This is ordinarily done by a switch on the dash of the car. In this Swiss magneto this is automatically done by swinging the spark lever to the full retard position. By doing this the interrupter cap is turned into such a position that a spring inside the cap makes a connection between the insulated contact and the armature shaft, thus doing away with a separate switch for this purpose. The separate switch may be used, however, if desired, as some automobile makers use it as a means of locking the car.

79. The Bosch High-tension Magneto.—The Bosch magneto, shown in Fig. 144, is of the conventional armature type generating two sparks during each revolution of the armature shaft. A longitudinal section of a Bosch magneto is shown in Fig. 145 and an end view in Fig. 146. The principal numbered parts are as follows:

1 Brass plate at the end of the primary winding.
2 Fastening screw for contact-breaker.
119 Long platinum contact screw.
118 Short platinum contact screw.
9 Condenser.
120 Lock nut for contact screw 119.
121 Flat spring for magneto interrupter lever.
105 Holding spring for interrupter cover.
10 High-tension collector ring.
11 Carbon brush for high-tension current.
12 Holder for brush.
13 Fastening nut for brush holder.
14 Spring contact for conducting the high-tension current.
15 Distributor brush holder.
16 Distributor carbon brush.
17 Distributor disc.
18 Central distributor segment.
20 High-tension terminals.
22 Dust cover.
123 Interrupter lever.
168 Interrupter housing and timing lever.
169 Cover for interrupter housing.
173 Low-tension brush.

The beginning of the primary winding is grounded to the armature core and the other end is connected to the brass plate, 1. In the center of this plate is the fastening screw, 2, which serves first, for holding the contact-breaker in its place, and second, for conducting the primary current to the platinum screw block of the contact-breaker. Screw, 2, is insulated from the contact-breaker disc, which is in metallic connection with the armature core. The platinum screw, 119, is fixed in the contact piece and receives the current from screw, 2. Pressed against this platinum screw, by means of the spring shown, is the magneto interrupter lever, 123, with platinum screw, 118, which is connected to the armature core and, therefore, with the grounded end of the primary winding. The primary circuit is, therefore, closed as long as the magneto interrupter lever, 123, is in contact with platinum screw,

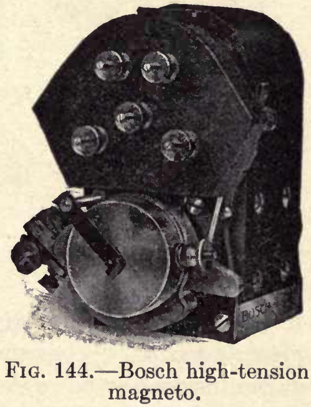


Fig. 144.—Bosch high-tension magneto.

119. The circuit is interrupted when the lever is rocked by the cam so as to open the contact. The condenser, 9, is connected across the gap formed when the contacts break.

The beginning of the secondary winding is connected to the insulated end of the primary so that the one forms a continuation of the other. The other end of the secondary winding leads to the collector ring, 10, on

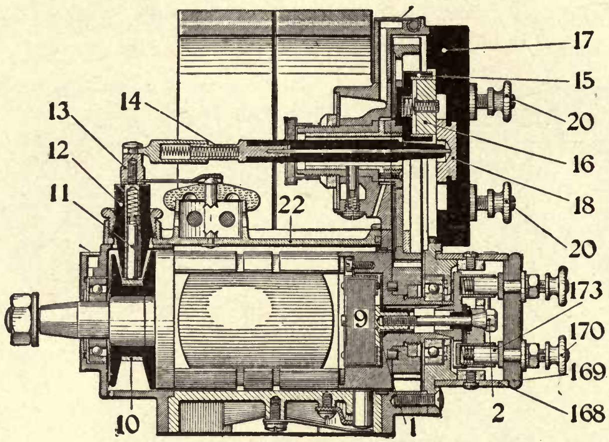


FIG. 145.—Section of Bosch high-tension magneto.

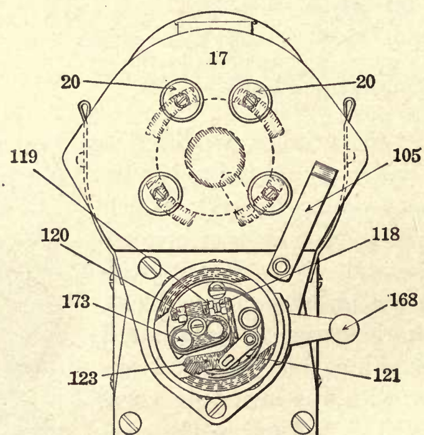


FIG. 146.—End view of Bosch high-tension magneto.

which slides a carbon brush, 11, held by the carbon holder, 12, and thus insulated from the magneto frame. From the brush, 11, the secondary current is conducted to the terminal, 13, through the spring connection, 14, to the center distributor contact, 18, and from there to the carbon brush, 16, the latter rotating with the distributor gear wheel.

In the distributor disc, 17, metal segments are embedded, and as the carbon brush, 16, rotates, it makes contact with the respective segments of the distributor. Attached to the metal segments of the distributor are the connection terminals, 20, to which are fixed the conducting cables to the spark plugs.

From the end of the secondary winding the high-tension current is distributed to the respective cylinders in the order in which they operate. The current produces the spark which causes the explosion; it then returns through the motor frame and the armature core back to the beginning of the secondary winding. The diagram of connections is shown in Fig. 147.

Safety Spark Gap.—In order to protect the insulation of the armature and of the current-conducting parts of the apparatus against excessive

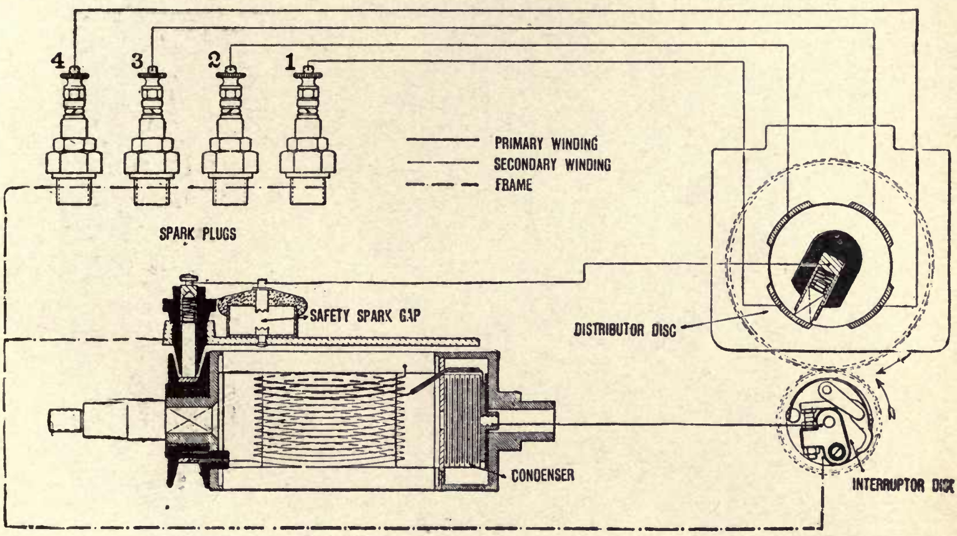


FIG. 147.—Wiring diagram of Bosch high-tension magneto.

voltage, a safety spark gap is provided as shown in Fig. 147. The current will pass through this gap in case a cable is taken off while the magneto is in operation or if the electrodes on the spark plugs are too far apart. The discharges, however, should not be allowed to pass through the safety gap for any length of time; special care has to be taken in this respect if the motor is equipped with a second system of ignition, in which case it is necessary to short-circuit the primary winding, as the continued discharge of the current over the safety gap is likely to damage the magneto.

80. The Bosch Dual System.—When a magneto is used with a heavy engine which can not be turned by hand at a sufficiently high rotative speed to produce a spark, it is necessary to use a dry or storage battery to produce the spark at these low speeds. The Bosch company offer three distinct systems of using the battery with the magneto; namely, the *dual* system, the *duplex* system, and the *two-independent* system. In the Bosch dual ignition system, the standard type of Bosch magneto is used with the application of two timers or interrupters. The parts of the regular current interrupter are carried on a disc that is attached to the armature and revolves with it, the blocks or segments that serve as cams being supported on the interrupter housing. In addition, the magneto is provided with a steel cam which is built into the interrupter disc and has two projections. This cam acts on a lever supported by the interrupter housing, the lever being so connected in the battery circuit that it serves as a timer to control the flow of battery current. These parts may be seen in Fig. 148.

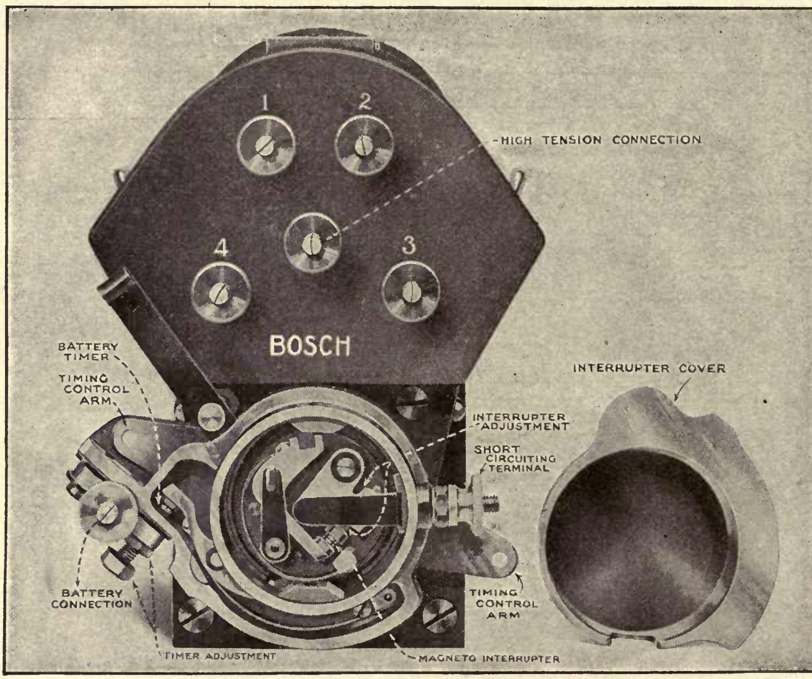


Fig. 148.—Bosch dual magneto, showing magneto interrupter and battery timer.

A non-vibrating transformer coil is used with the battery current to produce the necessary voltage.

It is obvious that the sparking current from the battery and from the magneto can not be led to the spark plugs at the same time; so a further change from the magneto of the independent form is found in the removal of the direct connection between the collecting ring and the distributor. The collecting ring brush shown in Fig. 145 as No. 11 and in Fig. 149 as No. 3, is instead, connected to the switch, and a second wire leads from the switch to the central terminal on the distributor. When running on the magneto, the sparking current that is induced in the secondary armature winding flows to the distributor by way of the switch contacts. When running on the battery, the primary circuit of the magneto is grounded, and there is, therefore, no production of sparking current by the magneto; it is then the sparking current from the coil that flows to the central distributor connection. It will thus be seen that of the magneto and battery circuits the only parts used in common are the distributor and the spark plugs.

The Bosch Dual Coil.—The Bosch dual coil used in the dual system consists of a cylindrical housing bearing a brass casting, the flange of which serves to attach the coil to a dashboard or other part. The coil is provided with a key and lock, by which the switch may be locked when in the "Off" position. This is a point of great advantage, for it makes it

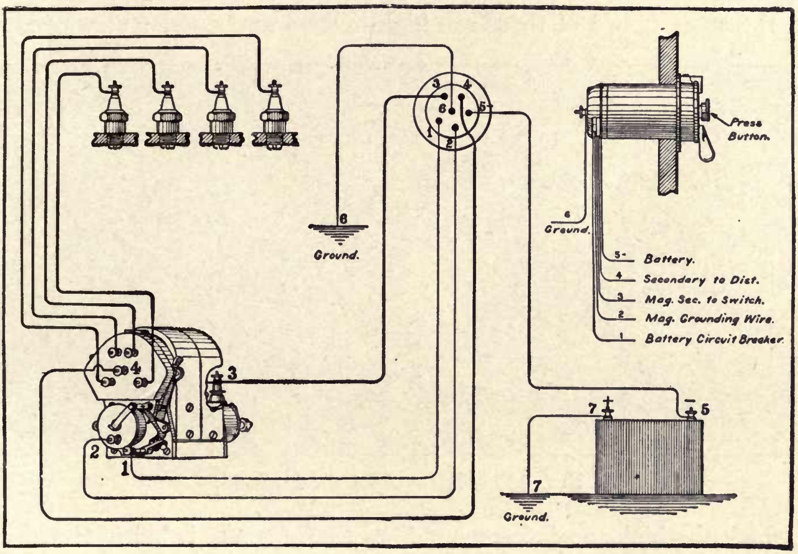


FIG. 149.—Wiring diagram for Bosch dual system.

unlikely that the switch will be left thrown to the battery position when the engine is brought to a stop. The absence of such an attachment is responsible in a large measure for the accidental running down of the battery. This locking device also prevents the unauthorized operation of the engine. The parts of the coil are shown in Fig. 150. In addition to the housing and end plate, they consist of the coil itself, the stationary switch plate, and the connection protector.

When the engine is running on battery ignition, a single contact spark is secured at the instant when the battery interrupter breaks its circuit, and the intensity of this spark permits efficient operation of the engine on the battery system.

Starting on the Spark.—For the purpose of starting on the spark, a vibrator may be cut into the coil circuit by turning the button that is seen on the coil body in Figs. 149 and 150. Normally, this vibrator is out of circuit, but the turning of the button places it in the battery primary circuit instead of the circuit-breaker on the magneto. A vibrator spark of high frequency is thus produced.

It will be found that the distributor on the magneto is then in such a position that this vibrator spark is produced at the spark plug of the cylinder that is ready to perform the power stroke; if mixture is present in this cylinder, ignition will result and the engine will start.

Connections.—In the wiring diagram of this system as shown in Fig. 149, it will be noted that while the independent magneto requires but one switch wire in addition to the cables between the distributor and spark plugs, the dual system requires four connections between the magneto and the switch; two of these are high-tension and consist of wire No. 3

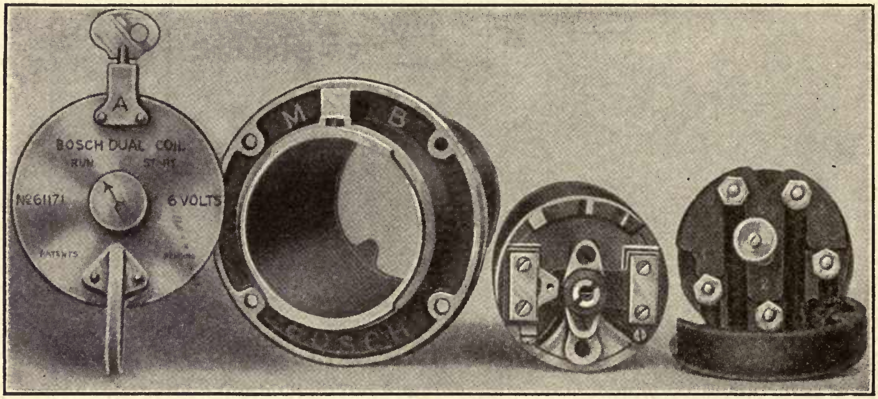


FIG. 150.—Parts of Bosch dual coil.

by which the high-tension current from the magneto is led to the switch contact, and wire No. 4 by which the high-tension current from either magneto or coil goes to the distributor. Wire No. 1 is low-tension, and conducts the battery current from the primary winding of the coil to the battery interrupter. Low-tension wire No. 2 is the grounding wire by which the primary circuit of the magneto is grounded when the switch is thrown to the off or to the battery position. Wire No. 5 leads from the negative terminal of the battery to the coil, and the positive terminal of the battery is grounded by wire No. 7; a second ground wire No. 6 is connected to the coil terminal.

81. The Bosch Duplex System.—This system also uses battery current for starting purposes, but in a different manner. The battery current is used in the primary circuit of the magneto armature to supplement the current generated by the magneto at low rotative speeds. To accomplish this without danger of the battery current destroying the magnetism of the magnets by flowing in the wrong direction through the armature winding, it is absolutely necessary that the positive and negative terminals of the battery be connected according to directions. It is also necessary to have a *commutator* in the interrupter housing, so that the battery current will always flow in the proper direction as the armature revolves. As shown in the wiring diagram of Fig. 151, the two wires from the battery lead to the switch, and two other wires lead from the switch to two terminals on the interrupter cover. Inside the cover are two brass segments each extending nearly halfway around the circle. On the interrupter, and revolving with it, are two brushes which receive the battery current and lead it through the interrupter or the winding in the same way that the armature current is flowing. The commutator segments and the brushes change the direction of the battery current

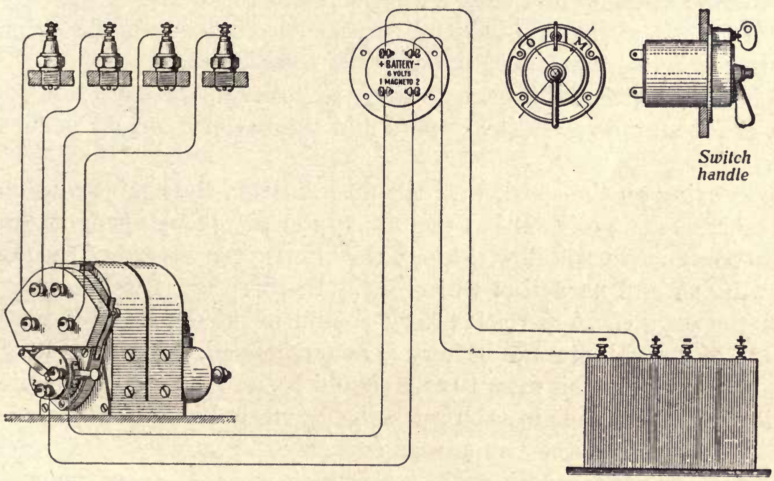


FIG. 151.—Wiring diagram for Bosch duplex system.

through the winding as the armature turns over, so that the current is always in the same direction with respect to the magnets and supplements their action instead of opposing them.

Operation.—There are three conditions of operation in this system. In starting on the spark with the engine and magneto at rest, the switch is thrown to battery position and the push button in the center of the switch is operated. In this condition, the battery current acts directly upon the winding of the magneto armature and the movement of the push button serves to make and break the primary circuit. The armature windings serve merely as a step-up transformer coil, resulting in the production of a secondary current which is led to the proper spark plug by means of the distributor.

When the engine is started by cranking, with the switch thrown to battery position, the action of the battery is to supplement the action of the magneto. The battery current flows through the coil within the switch housing and thus the action of the battery current is increased in the following manner: When the interrupter points are closed the battery current will flow through this coil and through the interrupter points, practically no current going through the primary winding of the armature. The switch coil is thus built up. When the interrupter points separate, the battery current has no other path than through the primary winding of the armature and must, therefore, take that path. At the same time, the break of the circuit through the interrupter produces an induced current in the coil winding much more powerful than the battery current. This induced current shoots into the primary winding of the armature and induces a very high voltage in the secondary winding of the armature, which high-voltage current is led to the spark plugs. It will thus be seen that the use of the switch coil greatly increases the action of the battery current. It is really this induced current that goes into the primary armature winding instead of the direct battery current.

When the switch is thrown to magneto position, the operation is the same as for an independent magneto and the battery current is cut out entirely.

In starting on the spark with the push button, the engine must have stopped in such a position that the interrupter points are open, otherwise the battery current will flow through the interrupter instead of the armature winding and no action will result. In this case it is necessary to crank the engine. A 6-volt battery should be used with this system. The use of a 6-volt storage battery is recommended. Dry cells may be used, however. In this case, 10 cells should be used in two parallel sets of 5 cells each, the 5 cells in each set being connected in series to give the desired voltage, and the two groups connected in parallel. The carbon posts of the dry cells are the positive terminals and this end of the battery should be connected to the terminal marked + on the switch.

82. Bosch Two-independent System.—The Bosch two-independent or double system consists of two complete and independent systems of ignition. One consists of a Bosch high-tension magneto system and the other of a Bosch high-tension distributor battery system.

The battery system is utilized for starting purposes and for emergency ignition in case of accident to the magneto system, which is used for ordinary service. The battery system consists of a combined coil and switch and a timer-distributor, which are completely independent of the magneto. The two systems are brought together at the switch, and the connections are such that the engine may be operated on the magneto with one set of plugs, or on the battery with the other set of plugs, or on the magneto and battery together, in which case both sets of plugs are used. Either the battery or magneto may be used for ignition with the other system entirely dismantled or removed from the engine. The wiring diagram for this system is shown in Fig. 152. In this figure the magneto is shown at the left with a single wire leading from the primary winding of the armature to the switch. When the magneto is cut out this connection, 2, is grounded through 6, thus giving the primary current a permanent path to the ground and eliminating the inductive action caused by the interruption of the flow through the interrupter contacts. The battery system operates essentially according to the description of distributor battery systems given in Chap. III.

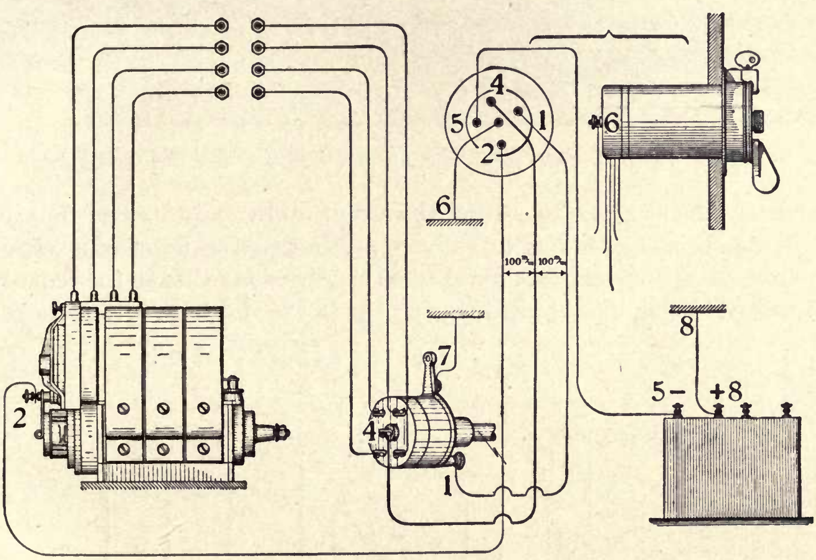


FIG. 152.—Wiring diagram for Bosch two-independent system.

83: Eisemann Dual Magneto with Automatic Spark Advance.—The Eisemann magneto is made in a number of types following more or less the conventional arrangements. The dual system with the automatic spark advance will be described here because of the unique features which it possesses.

The precise time at which the charge in a cylinder should be fired is essentially a matter of engine speed, although other considerations affect it to some extent. If the position of the spark control lever is left to the judgment of the operator, it may result either in too late a spark with the consequent loss of power and over-heating of the engine, or in too early a spark with knocking in the engine and possible damage to the bearings. With a car in the hands of the average driver, more satisfactory results can be obtained by having the time of the spark automatically varied by the engine as its speed varies. The provision for this on the Eisemann magneto is shown in Fig. 153, which shows the spark advance mechanism attached to the armature of the magneto. The pair of weights in the foreground are attached through suitable links to a spiral sleeve between the magneto shaft and the armature. As the speed increases, these weights begin to spread as the result of the increased centrifugal force and exert a longitudinal pull on the spiral sleeve. This motion of the

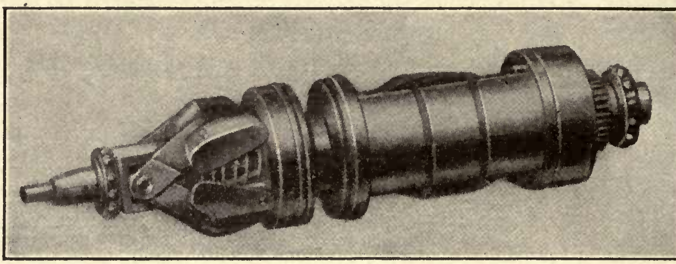


FIG. 153.—Eisemann armature with automatic spark advance mechanism.

sleeve within the armature causes the armature to be rotated on the shaft in the direction of rotation, thus advancing the spark as the speed increases. The reverse operation takes place when the speed is reduced, the centrifugal weights being drawn together and the sleeve slid back into the arma-

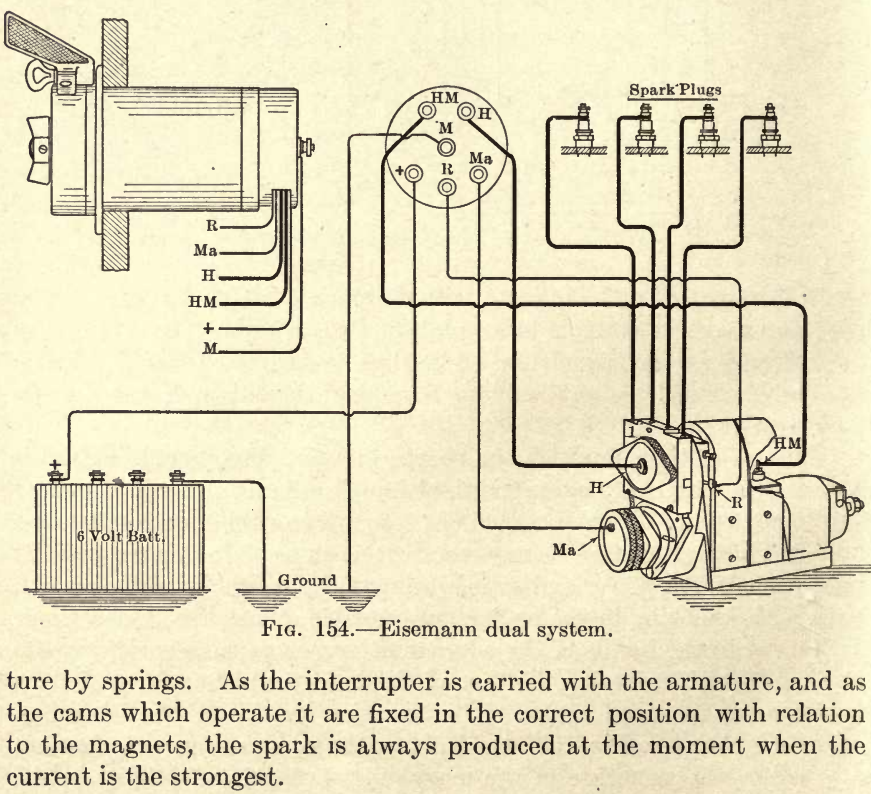


FIG. 154.—Eisemann dual system.

ture by springs. As the interrupter is carried with the armature, and as the cams which operate it are fixed in the correct position with relation to the magnets, the spark is always produced at the moment when the current is the strongest.

This automatic spark advance may be used either with an independent magneto or with the dual system. Figure 154 shows the Eisemann dual magneto with this spark advance. The governor mechanism is contained in the small case at the right of the magnets. In its operation as a dual magneto this machine is distinctive in having the timer for the battery system located on the distributor shaft, while the magneto interrupter is, as usual, carried on the armature shaft. The advantage claimed for this arrangement is that one circuit-breaker may be out of service without affecting the operation of the remaining one. There are also two separate condensers, in fact, the only parts of the ignition system that are used in common by both battery and magneto are the spark plugs and the distributor. The double-wound coil on the switch is used with the battery system, thus giving a battery system that is of the high-tension distributor type described in Chap. III.

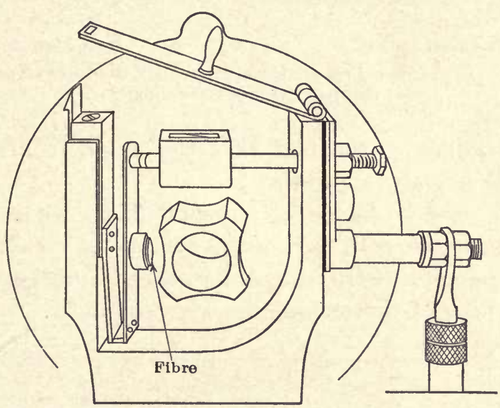
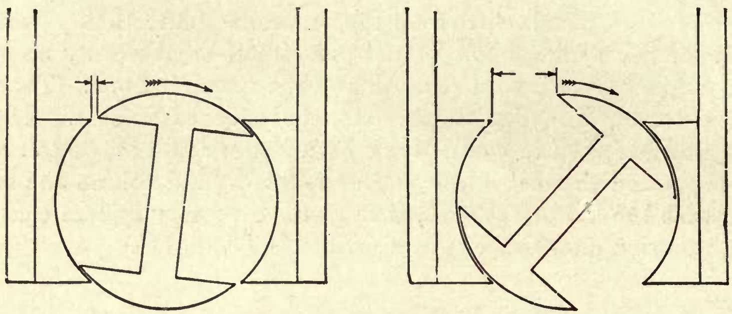


FIG. 155.—Eisemann battery circuit breaker.

The battery circuit-breaker is placed just back of the distributor and has its cam on the distributor shaft. This necessitates a four-point cam for a four-cylinder engine and a six-point cam for a six-cylinder engine. The construction of the circuit-breaker is shown in Fig. 155. The movable contact point is carried on the upper end of the vertical spring, which also carries a fiber bumper near its center. This bumper is struck by the points of the cam as it revolves.

84. The Mea Magneto.—This unique machine is designed to give a wide range of ignition without affecting the value of the sparking current. In the ordinary horseshoe type of magneto with fixed magnets, any change in the time of the spark means that the spark is produced at a different position of the armature with respect to the magnets, as shown in Fig. 156. This naturally limits the spark range to that part of the current wave in which suitable ignition can be obtained. The Mea magneto shifts the magnets with the interrupter, as shown in Fig. 157, so that the armature is always in the same relation to the magnets regardless of the advance or retard of the spark-timing lever. With the standard types of Mea magnetos the sparking range is from 45° to 70°, and if necessary this range can be increased. Although they are also offered with the dual system, the makers claim that the battery starting

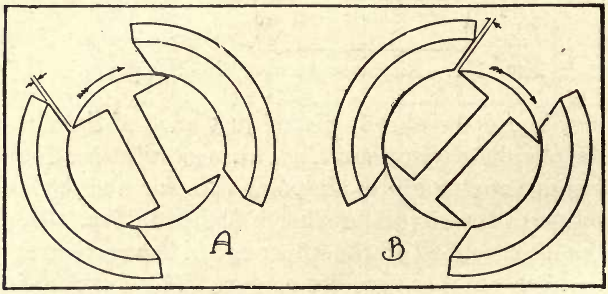


Advanced spark. Retarded spark.

Fig. 156.—Horseshoe-type magnetos—relative positions of armature and magnets at the moment of sparking.

is not needed because of the fact that the magneto always takes full advantage of the armature current.

The magnets are bell-shaped, as shown in Fig. 158, and are so placed that their axis coincides with that of the armature. The exterior is seen in Fig. 159, the magnets, distributor, and interrupter housing being cradled in the frame or base of the magneto. The timing lever is shown at the



Advanced spark. Retarded spark.

Fig. 157.—Mea magneto—relative position of armature and magneto at the moment of sparking.

right attached directly to the magnets. Figure 160 shows the internal arrangement. The armature is of quite conventional design with the driving connection at 32, the condenser at 21, the high-tension collector ring at 4, and the interrupter at the extreme right. The latter is built on a disc, 13, which carries the platinum contacts at 12; the movable contact is adjustable and is supported by a spring, 14; this is in turn fastened to the insulated plate, 15, which receives the armature current through the screw, 16. The interrupter is actuated by the fiber roller, 17, which is also carried by the disc, 13. This roller is actuated by a cam

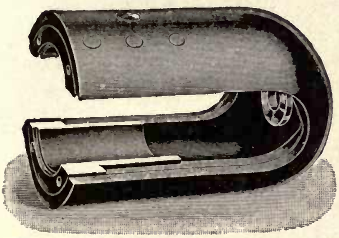


FIG. 158.—Bell-shaped magnet of Mea magneto.

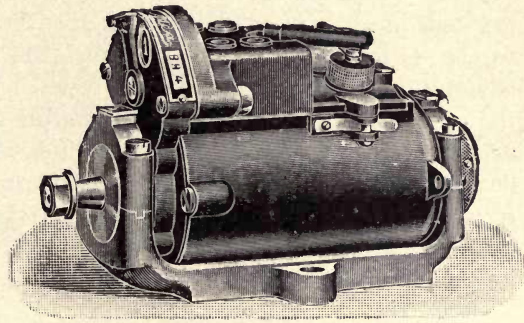


FIG. 159.—The Mea magneto.

disc, 18, which is provided with two projections and is attached to the field structure. In this way, the spark is secured at certain definite relative positions of the armature and magnets.

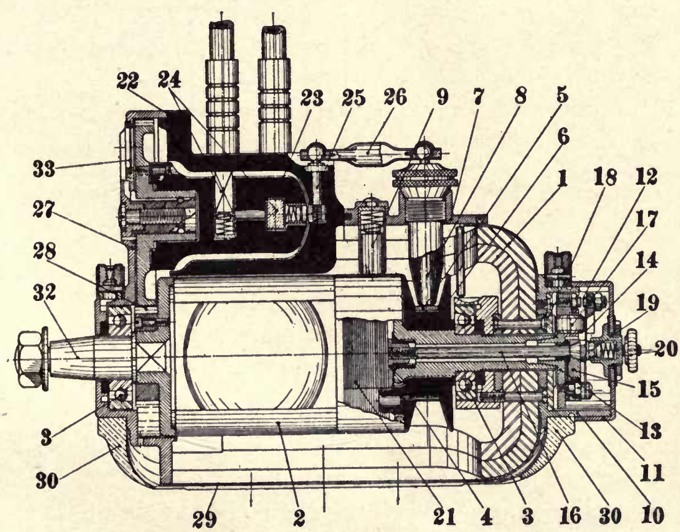


FIG. 160.—Section of Mea type BH4 magneto.

85. Simms Dual High-tension Magneto.—This magneto possesses a noteworthy feature as seen on the 1916 Maxwell automobile. This consists of a switch by which battery current is supplied to the magneto for starting purposes at the same time that the starting pedal to the starting motor is pressed. This arrangement is illustrated in Fig. 161, which shows the magneto, the battery, the coil in the battery circuit, and the starting switch, which also closes the battery circuit at the same time that the starting motor switch is closed. When the starting switch is released, the battery current is also cut off from the magneto and it takes up its regular operation as a high-tension magneto. There are four dry cells in series in the battery circuit, the carbon pole being connected to the + terminal on the magneto. The magneto is provided with a commutator to keep the direction of the battery current, when used, in the proper direction through the armature so as not to destroy the magnetism of the magnets. The single magneto interrupter and the condenser are used for both battery and magneto systems. When the battery current is turned on, by the starting switch, the current flows through the coil and the interrupter of the magneto. When the interrupter circuit is broken a powerful current is induced in the coil in a

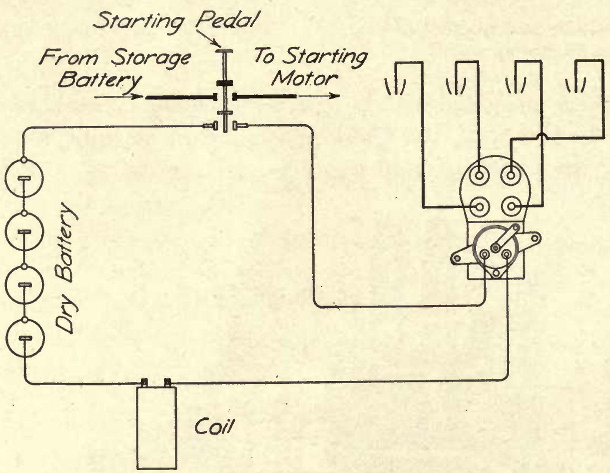


FIG. 161.

manner similar to the operation of a kick coil in a make-and-break ignition system. This current is discharged into the primary winding of the armature, since that is the only path left closed to the current. This causes the armature to act like a step-up transformer coil and produces a powerful sparking current in the secondary winding. This is led to the spark plugs in the usual manner. When the engine has taken up its cycle, the foot is taken from the starting pedal and the battery circuit is thus broken. The magneto then takes up its regular action without the assistance of the dry battery.

The single wire from the interrupter to the junction plug is for the purpose of grounding the primary current to cut off the ignition, in the usual manner.

86. The Dixie Magneto.—The generating principles of this novel machine were described in Chap. VI and will not be repeated here save to recall that the coil is wound between stationary field pieces through which the flux is reversed by the revolving rotor. The coil in this machine has a double winding, for the primary and secondary circuits. An elementary diagram is shown in Fig. 162, from which it will be seen that the primary circuit is of the interrupted primary current type. The breaking of the primary circuit induces the high-voltage current in the secondary winding and this is directed to the plugs by a conventional distributor.

Since the coil windings are not on a revolving armature, the interrupter is built like that for a low-tension magneto instead of that for a high-tension magneto, that is, the interrupter points are built in the interrupter housing and the cam is revolved on the rotor shaft.

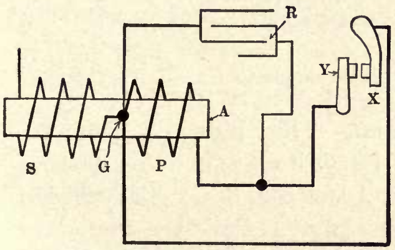


FIG. 162.—Primary circuit of Dixie magneto.

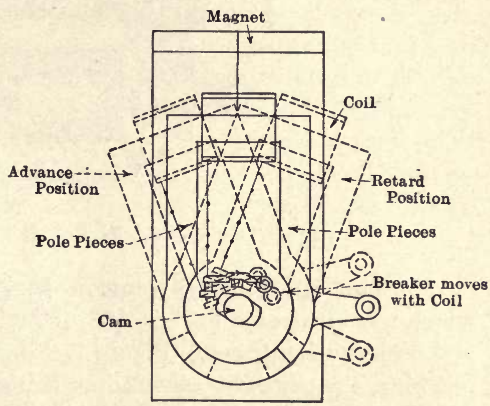


FIG. 163.—Showing movement of Dixie coil and pole pieces with the interrupter or breaker.

Another feature of this magneto is that the field pieces carrying the coils are shifted in position with the interrupter, as shown in Fig. 163, thus obtaining the maximum spark at all positions of the interrupter.

87. The Pittsfield High-tension Magneto.—The principles of this inductor magneto were also explained in Chap. VI (see Fig. 111). The actual construction of this magneto is shown by the longitudinal section of Fig. 164. The coil core, 5, has a double winding, both primary and secondary. The interrupter cam, 15, operates the interrupter lever to break the primary circuit at the same instant that the inductors are shifting the flux out of the core, 5. This produces an induced current of high voltage in the secondary winding.

Another feature of this machine not shown in the previous discussion is the arrangement for shifting the magnetic field as the interrupter housing is shifted to advance or retard the spark. When the machine is to be used for variable ignition, a gap is left between the poles and the armature and four-pole pieces or shoes are placed in this space and mounted so that they can be shifted with the interrupter. As these pieces collect the magnetic flux and direct it to the inductors the path of the magnetic field will be shifted as these pieces are shifted. Figure 165 shows the positions of these pole pieces for full retard and full advance.

This magneto is cut out in the usual manner by grounding the primary current. It is also built as a dual magneto using battery current for starting.

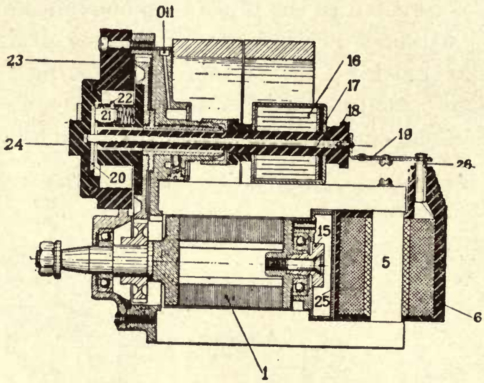


FIG. 164.—Section of Pittsfield magneto.

88. The K.-W. High-tension Magneto.—This inductor magneto, which was illustrated in Figs. 108, 109 and 110, is built in both low-tension and high-tension types. Figure 110 showed a section of the high-tension machine, the primary coil winding being shown at 114 and the secondary winding at 113 in Fig. 110. The interrupter is included in the circuit of

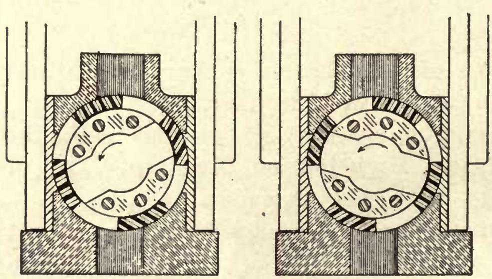


FIG. 165.—Shifting polepieces of Pittsfield magneto.

the primary current and this current is interrupted at some point during the peak of the current wave. The secondary current thus induced in the secondary winding is distributed in the usual manner. As this machine has stationary windings, the interrupter has its contacts carried in the housing, while the cam rotates with the armature. The safety spark gap is shown at 118 and the condenser at 126 of Fig. 110.

CHAPTER IX

DIRECT-CURRENT GENERATORS

89. Direct and Alternating Currents.—In the magnetos described in Chaps. V, VI, VII, and VIII, the current from the armature windings was alternating current, reversing its direction of flow as the armature changed its position. With the shuttle-wound armature there were two waves of current for each revolution of the armature. During a part of the armature revolution a wave of current was generated in one direction; when the armature had turned 180° there was a wave of current in the opposite direction. That the circuit outside of the magneto received this kind of current from the armature winding was due to the fact that a collector ring and a brush were used for collecting the current from the armature winding. One end of the armature winding was fastened to this ring. The result was that the brush

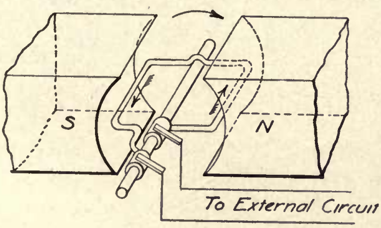


FIG. 166.—Elementary alternating-current generator.

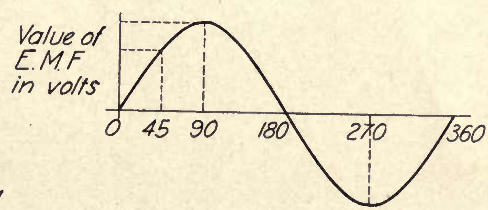


FIG. 167.

received current according to the position of the armature winding between the pole pieces of the magneto. It might be no current at one position; then there would be a wave of current in one direction as the armature changed its position; then it would die down; and then as the armature turned over there would be a wave of current in the opposite direction.

It is possible, however, to so construct a magneto or other generator that a direct current, or current always flowing in the same direction, can be taken off from the armature windings. For many purposes this is desirable and often necessary. Storage batteries, for example, can be charged only by a direct current. With a direct current there is not the necessity of having the magneto carefully timed to the engine, since a sparking current can be obtained at any position of the armature.

Although we have frequently spoken of the current from an armature, it is really voltage or "electromotive force" (e.m.f.), that is generated in the armature winding; that is, an electrical pressure. The amount of current that flows through the circuit as a result of this e.m.f. depends on the relation between this voltage and the resistance of the circuit, just as the amount of water that will flow through a pipe depends on the pressure that is behind it and the resistance of the pipe.

Figure 166 represents an elementary type of alternating-current generator with the armature core left out and with a single turn of wire to represent the armature winding. The two ends of the winding are attached to two collector rings on the shaft. As the mangetic flux goes across the gap from the North to the South pole pieces, the generation of an e.m.f. in the wire depends on the cutting of the lines of force by the wires of the winding. With the motion of the coil as indicated, the direction of the current flow will be as shown by the arrows on the wires. When the coil is vertical, the wires will be moving at that instant parallel to the flux and there will be no voltage generated in the wires. When the coil turns 180° from the position shown, the two sides of the coil will have exchanged positions, but the collector rings will be still connected to the same ends of the coil, so that the direction of current flow will be reversed. The variations of the voltage or e.m.f. for one complete revolution of the winding will be similar to that shown by the diagram of Fig. 167. The highest voltage would be obtained in this simple generator when the coil was horizontal, as in Fig. 166, and there would be a zero voltage when the coil was vertical.

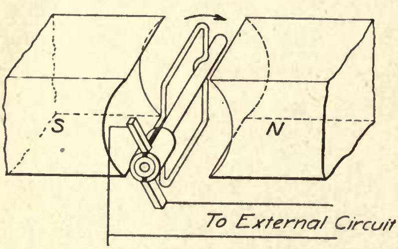


Fig. 168.—Elementary direct-current generator.

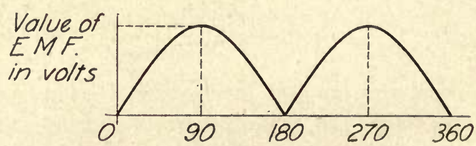


Fig. 169.

90. Commutators.—To get a direct current from this generator, it would be necessary to make some provision so that the connections to the external circuit would be reversed as the coil turned over. This is shown in an elementary way in Fig. 168, where the ends of the coil are connected to the two halves of a split ring, these halves being insulated from each other. On this ring are two brushes which receive the current from the armature winding and lead it through the external circuit. This device would give the diagram of Fig. 169 for the voltage received from the winding as it makes one revolution. As the winding reached the position of zero voltage, as illustrated in Fig. 168, the segments of the commutator would change under the brushes, so that the next current wave would be in the same direction through the outside circuit.

A single loop of wire, of course, does not deliver a steady current, although the current is always in the same direction. As will be seen from Fig. 169, that part of the wave between 180° and 360° has been reversed in direction from that in Fig. 167, but it has the same variation in value and has the same zero and maximum points as the alternating-current wave. In commercial practice, a large number of turns or coils are used on the armature, placed at regular intervals around the armature, and a correspondingly large number of segments are used on the commutator. In this way a voltage diagram is produced similar to that shown in Fig. 170.

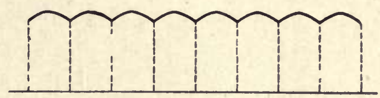


FIG. 170.

Figure 171 shows the construction of a typical armature for a direct-current generator. At the left is the commutator, made up of a number of copper segments insulated from the shaft and from each other. The core of the armature, like those previously described, is made up of thin sheets of iron or soft steel. The sheets are slotted at regularly spaced intervals around the circumference. The coils are wound in these slots. By having a number of coils and commutator segments, the voltage delivered to the brushes is practically constant throughout the revolution of the armature.

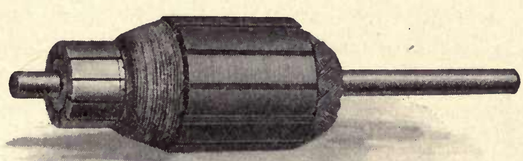


FIG. 171.—Direct-current armature.

91. Classification of Direct-current Generators.—These direct-current generators may be classified according to the manner in which the magnetic field is produced.

They are called *Magneto Generators* or *Direct-current Magnetos* when the field is produced by permanent magnets.

A part or all of the current from the armature or some other source may, however, be used to produce the magnetic field by means of electro-magnets.

These are called *Shunt Generators* if the field coil is in a shunt circuit so that it receives only a part of the armature current.

When the entire armature current is led through the field coil the machine is called a *Series Generator*.

When both types of field coils are used, the machine is called a *Compound Generator.*

When the machine is excited by means of its own current it is said to be *Self-excited;* when excited by current from some other source, it is said to be *Separately Excited.*

Figure 172 shows a view of a four-pole shunt generator. The field is excited by a winding that is connected in parallel with the outside

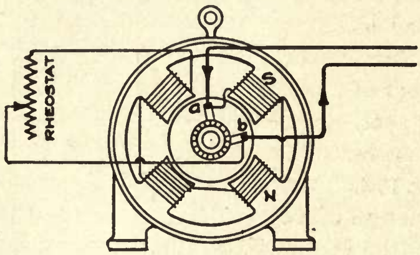


FIG. 172.—Shunt-wound direct-current generator.

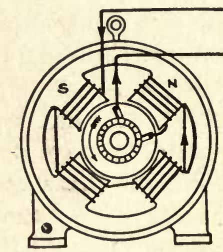


FIG. 173.—Series-wound direct-current generator.

circuit. The field current can flow through this winding whether the external circuit is open or not. For this reason the shunt coils are wound of many turns of very fine wire. It is not desirable that a large part of the current be allowed to flow through the coils, as every bit thus used is taken from the outside circuit and thus renders the generator less efficient. A regulating rheostat or resistance can be used if desired, as shown in the figure, to control the strength of the fields.

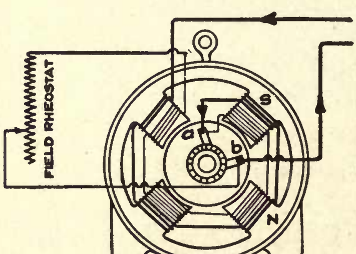


FIG. 174.—Compound-wound direct-current generator.

Figure 173 shows a series generator. Here all the current that flows from the machine passes through a coarse winding around the pole pieces before passing to the outside circuit. In this machine, the more the current used in the external circuit, the more will be the current flowing through the field coils, and hence the stronger will be the magnetic field and consequently the greater will be the voltage generated.

Figure 174 shows the arrangement of a compound generator, having both shunt and series field coils. Each of these types of machines has certain characteristics which make it desirable for certain purposes and not for others.

92. Direct-current Magnetos.—Direct-current magnetos are frequently used for ignition purposes, either for make-and-break or jump-spark. They do not need to be accurately timed to the engine shaft like alternating-current magnetos, but may be belt-driven or friction-driven. Figures 175 and 176 show two Hendricks direct-current magnetos equipped for friction and belt drive respectively.

The armature resembles in form that shown in Fig. 171. It is made with a laminated core of soft steel and is wound with cotton-

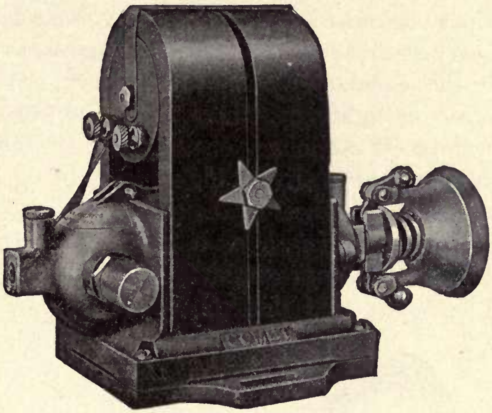


Fig. 175.—Hendricks friction-driven direct-current magneto.

covered magnet wire. Figure 177 shows the construction of the brush holders for these machines. The coiled spring, being compressed by the cap shown in the hand, presses the brush against the commutator, thus producing good electrical contact at all times. The brushes are

Fig. 176.—Hendricks belt-driven direct-current magneto.

made of bronze gauze with a carbon core and with the springs soldered to the brushes. The carbon core gives a smooth contact surface while the gauze overcomes the resistance to the flow of current through the carbon. These brushes receive the current from the commutator segments and conduct it to the outside circuit.

The magneto of Fig. 175 has a jump-spark coil mounted in the arch of the magnets. The machine of Fig. 176 is intended for both lighting and ignition in conjunction with a storage battery. Under the arch of the magnets is mounted an automatic cut-out by means of which a switch is closed and the generator thrown into the circuit when the speed of the generator is sufficient to generate over 6 volts, which is the voltage of the battery. When this cut-out is closed the generator is charging the battery. When the cut-out is open the battery is supplying all the current for ignition or lighting. These machines are sold for ignition and lighting purposes for stationary engines, launches, and automobiles. They are driven at a comparatively high speed, being belt- or friction-driven, usually from the flywheel of the engine.

Governors.—The field strength of a magneto is constant and the voltage generated will be approximately proportional to the speed of rotation. It is necessary that this voltage be regulated so that it will

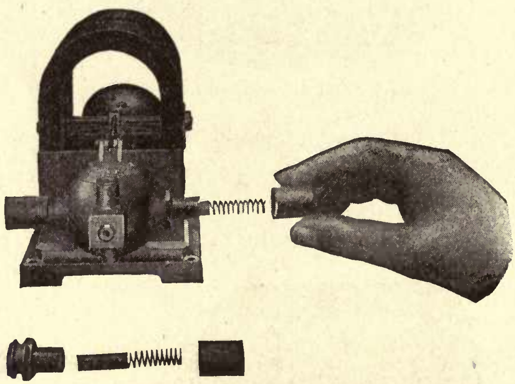


FIG. 177.—Hendricks brushes and brush holders.

not be excessive for the storage battery or ignition coil. The most common method of regulation is to control the speed of the magneto armature by means of a governor. Figures 175 and 176 show two of these governors in which the action of centrifugal force throws the pivoted weights out against the action of the coiled springs. In Fig. 175 this draws the friction wheel away from contact with the flywheel of the engine when the speed exceeds the desired amount. In Fig. 176 the outer half of the V-pulley is drawn to the right, thus releasing the belt and causing it to slip. By the action of these governors the speed, and consequently the voltage, of the machines is kept constant. The automatic cut-out previously mentioned in connection with Fig. 176 is also operated by the governor, opening or closing the switch according to the speed of the armature.

Figure 178 shows some of the different possible positions for setting the friction wheel of a direct-current generator so that it will receive its motion by friction contact with the flywheel. When the speed of the engine causes the generator armature to exceed the desired speed, the weights expand under the action of the centrifugal force and withdraw the friction wheel from contact with the flywheel. When the speed of the armature again drops to normal, the weights are drawn together by the springs and the friction wheel again comes into contact with the flywheel. For a flat-belt drive the pulley is mounted free on the armature shaft and drives the armature through a clutch which is released by the expanding weights when the speed rises above normal.

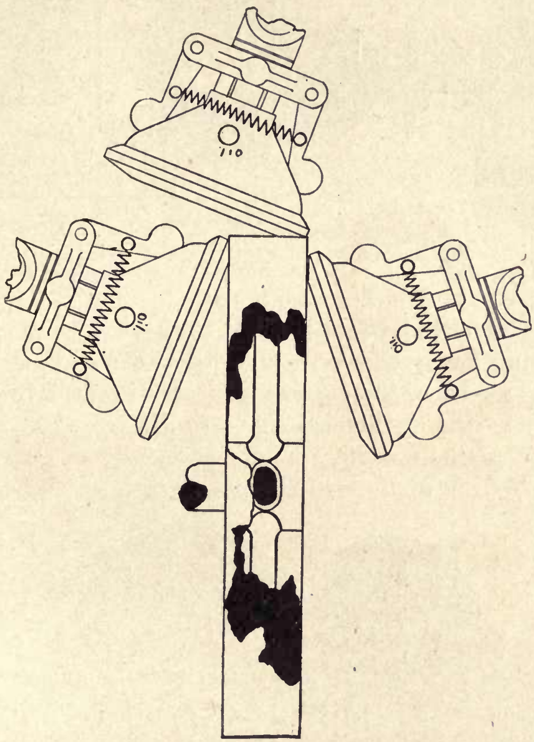


Fig. 178.—Different positions for setting friction drive.

Figure 179 shows the Motsinger direct-current magneto with friction wheel and governor. This machine is unusual in its construction. There are 15 thin magnets instead of the two, three, or four wider magnets of other makes, and these are so shaped at the ends that no pole pieces are required. This eliminates one joint in the magnetic circuit and reduces the resistance to the flow of the magnetic lines of force. This magneto is for use with make-and-break ignition systems.

Figure 180 shows a line-wiring diagram for connecting the magneto, with auxiliary battery for starting purposes. Any engine which can be turned over the compression by hand can be started directly on the magneto, it being necessary merely to close the switch and turn the engine until it takes up its action. For larger engines, the battery auxiliary can be used. This magneto also uses a friction drive with a governor which removes the friction wheel from contact with the flywheel when the speed exceeds the desired amount.

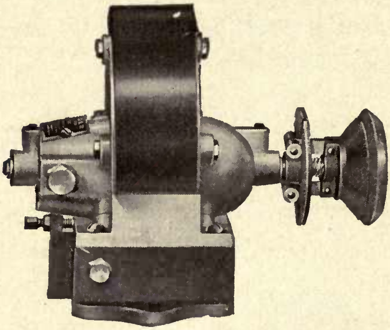


FIG. 179.—Motsinger direct-current magneto.

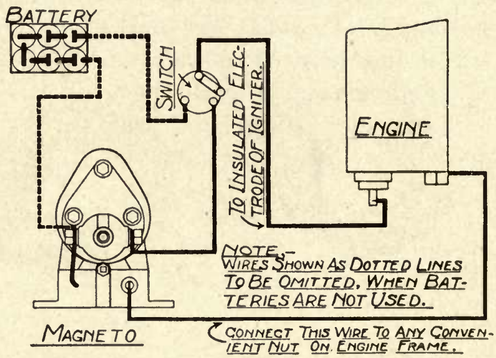


FIG. 180.—Wiring diagram for Motsinger magneto.

93. Direct-current Generators.—Figure 181 shows the Dayton ignition dynamo or generator. This is a self-excited, shunt-wound machine, using a part of the current from its own armature to excite the fields. The armature of this machine was illustrated in Fig. 171. The cast-iron frame of the machine has two inwardly extending pole pieces which are excited or made into electromagnets by the current passing

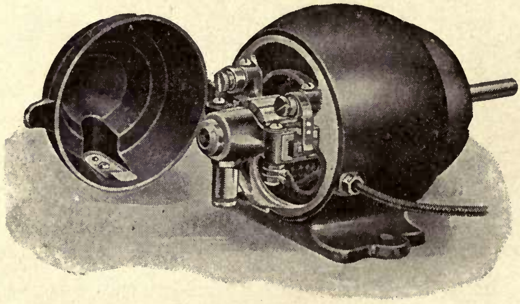


FIG. 181.—Dayton direct-current ignition dynamo.

through the field coils shown in Fig. 182. These coils are slipped over the pole pieces and cause them to become electromagnets when current from the armature passes through the coils. The coils are so wound that one of the pole pieces becomes a North pole and the other a South pole, the flux thus produced between the two poles passing through the armature just as when permanent magnets are used to produce the flux. The rotation of the armature in the magnetic field causes the armature coils to cut this flux and thus an e.m.f. or voltage is generated in the armature winding. This armature has 12 coils connected end to end, each connection being also brought out and soldered to one of the 12 segments of the commutator. The construction of the commutator is shown in Fig. 183. The 12 segments are insulated from each other and

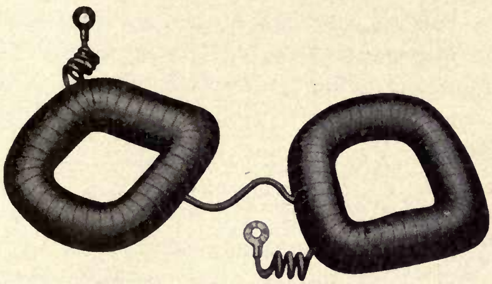


FIG. 182.—Dayton field coils.

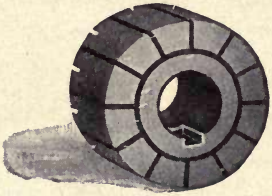


FIG. 183.—Dayton commutator.

from the shell by sheet mica. Two brushes made of graphite and bronze collect the current from the commutator.

The voltage generated by this machine, and hence the current in the external circuit, other conditions being the same, is almost directly proportional to the speed of rotation of the armature. To secure a constant voltage it is therefore necessary that the speed be accurately

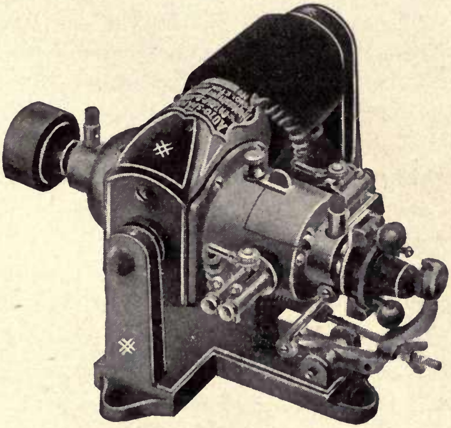


FIG. 184.—The Motsinger auto-sparker.

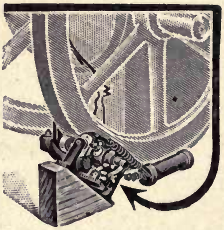


FIG. 185.—Auto-sparker in position.

regulated. This is accomplished by the use of a friction governor similar to those shown in Figs. 175 and 176.

The Motsinger "Auto-sparker" shown in Fig. 184 is a direct-current dynamo similar in operation to those just described. The principal difference is in the method of mounting and governing. The governor is on the opposite end of the armature shaft from the friction wheel

The entire generator is cradled in a frame as shown in Fig. 186 and is tilted about this axis to place the friction pulley in contact with or remove it from contact with the flywheel. This device permits of the use of a square face on the friction pulley. When normal speed is exceeded the governor weights fly out and the machine is tilted so as to draw the friction pulley from contact with the flywheel, thus tending to keep a constant speed of rotation. This constant speed results in a constant electrical pressure, or voltage, and current flow. Figure 185 shows the auto-sparker mounted in contact with the flywheel of an engine.

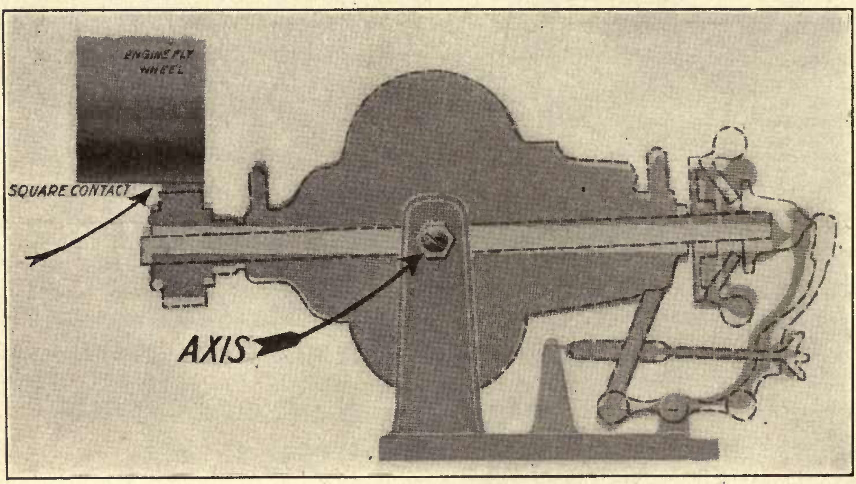


FIG. 186.—Showing action of governor on auto-sparker.

94. Automobile Starting, Lighting, and Ignition Generators.—With the general adoption of electric devices for starting automobile engines and for lighting the cars, the natural tendency has been to use this source of current for ignition purposes as well. This system provides a direct-current generator which is driven by the engine and which, when running above a predetermined speed, furnishes current for ignition and lighting, the excess current being used to charge a storage battery. In starting, and when running below this predetermined speed, the storage battery furnishes the necessary current for all purposes. In what is known as the "single-unit system" the generator is converted into a motor for use in starting the engine. In the "two-unit system" there are separate motors and generators. These generators, with the storage batteries, give a constant source of direct current which is frequently used as the source of current for ignition purposes, using a mechanical interrupter, a transformer coil, and a distributor for the secondary current, as described in Chap. III. Among the ignition systems used in this way are the Delco, the Atwater Kent, the Connecticut, the Remy, and the Westinghouse.

The generator must be so arranged that it will be out of connection with the battery when the voltage generated, due to low speeds, is below that of the storage battery, thus preventing a discharge of the battery back through the generator. At such times the battery furnishes the ignition current. When the voltage of the generator exceeds that of the battery the connection is made and the excess current is used in charging the battery. The generator must be so adjusted that it will maintain a charge in the battery to balance the current demands on the battery when starting and when running at slow speeds. As different drivers run at different speeds, and as city driving requires more frequent starting than touring, it is desirable to have a means of adjusting the speed at which the generator will begin to charge the battery to fit the conditions under which the car is used.

The generator is usually driven in a fixed relation to the speed of the engine, either by a belt, a chain, or by gearing.

If the voltage of the generator were allowed to increase in proportion to the engine speed, as might normally be expected, it would result in excessive voltages at high speeds and thus in excessive charging rates for the batteries. In some of the earlier generators, a friction governor was used to maintain the speed of the generator constant after it had reached a determined speed. At present there are three general methods of controlling the generator output, namely, the differential field winding, the field brush system, and the vibrating field regulator, or relay.

95. Differential-wound Generator.—There are many machines using the different types of generator control above mentioned and no attempt will be made to describe them all. Only typical examples will be taken. A Westinghouse generator will be described to illustrate the differential-wound type.

Westinghouse Generator.—Westinghouse systems are made for ignition only, for lighting and ignition, for starting and lighting (without ignition), or for starting, lighting, and ignition. This article will describe a generator as built for lighting and ignition only.

The generating outfit consists of a differential-wound generator, Fig. 187, operated by a chain or gear drive from the engine. This machine also carries the primary interrupter and the secondary distributor of the ignition system mounted at the right-hand end in Fig. 187. These devices were illustrated in Figs. 54 and 58 in Chap. III and will not be again described here.

Figure 188 shows the principal parts of the generator. The armature is similar to those previously described for direct-current generators. In the upper part of the frame are seen the field coils for energizing the field magnets of the generator. There are two field poles in this machine, the upper one being visible just below the bottom of the field coils. The lower one is at the base of the machine and receives its magnetism through the sides of the frame from the upper end of the coil.

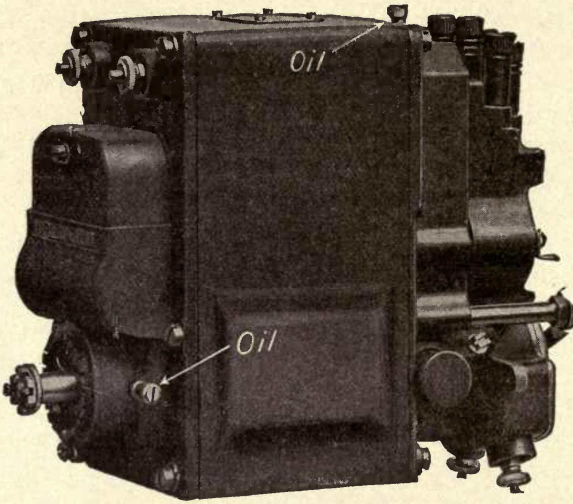


Fig. 187.—Westinghouse ignition and lighting generator.

The field coil consists of two windings. One is a shunt winding, so that the current flowing through it depends on the voltage produced by the machine, regardless of whether or not it is supplying current to the external circuit. The other is a series winding through which flows all

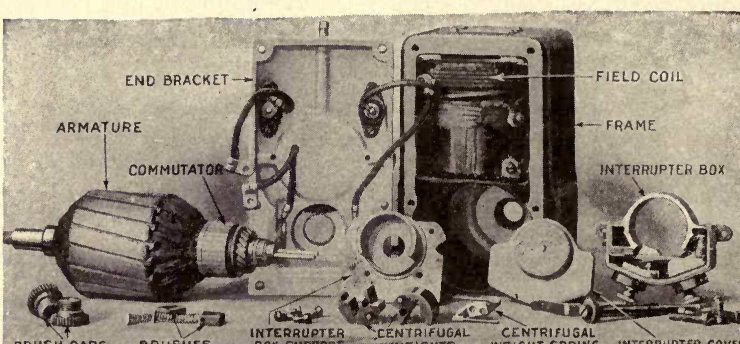


Fig. 188.—Parts of Westinghouse generator.

the current delivered by the machine to the external circuit. This series winding is so wound as to oppose the magnetizing action of the shunt winding. This controls the value of the charging current. With a constant field strength the voltage of the generator would be almost proportional to the speed, and with the shunt winding alone it is evident that at high engine speeds the voltage of the generator would be excessive. By having the series winding of the field so wound as to oppose the action of the shunt winding, the field strength is reduced as the amount of current delivered by the generator increases, thus tending to keep the output of the generator within reasonable limits for all speeds.

When the engine is not running, or when running at very slow speeds, the current for lights and ignition is supplied entirely from the storage battery. A magnetically operated switch in the generator automatically connects the generator to the battery and the lighting and ignition system when the voltage of the generator exceeds that of the battery, which occurs at a car speed of about 8 miles an hour on direct drive. Of course, when running on the transmission gears the switch closes at a lower car speed, since it is the engine speed and not the car speed which governs the action of the switch. The amount of current which the generator supplies to the storage battery depends on the current consumed in the

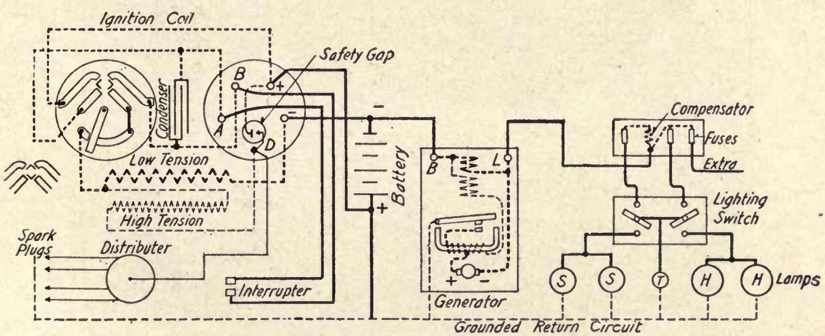


FIG. 189.—Diagram of connections for Westinghouse ignition and lighting generator.

lamps and ignition system and the speed of the engine, the excess current, if any, being absorbed by the battery.

Figure 189 shows the internal wiring diagram of this system. At the left is shown the ignition system, with the mechanical interrupter, the transformer coil, and the distributor. At the right is the lighting system with the switches and lamps. The lighting switch will be seen to be so arranged that the tail light is thrown on when either the side lights or head lights are turned on. In the center of the figure are shown the generator and the battery. The armature is indicated in the lower part of the generator by a circle with the positive and negative brushes indicated. In the upper part of the generator are indicated the shunt and series field windings. Below the field windings is seen the magnetic switch, with a fine shunt winding connected to the shunt winding of the field coil and with a series winding connected through the armature on one side and through the ground on the other side to the battery. When the voltage of the generator reaches the desired value for charging, the current through this shunt winding is sufficient to close this switch and thus connect the positive brush of the generator to the ground and give it a complete connection to the battery and the lighting and ignition system. It will then supply part or all of the current requirements and, if the output is sufficient, will charge the battery. If for any reason, such as slow speed or the stopping of the generator, the current from the battery should start to flow in the reverse direction into the generator, this current flowing in the opposite direction through the series winding of the switch would demagnetize the core and open the switch.

96. Field-brush Control System.—This system uses one or two separate brushes on the generator commutator for collecting the current which is used to excite the fields of the generator. The voltage which is supplied to the brushes of a generator depends upon the position of those brushes with respect to the magnetic field. This relative position

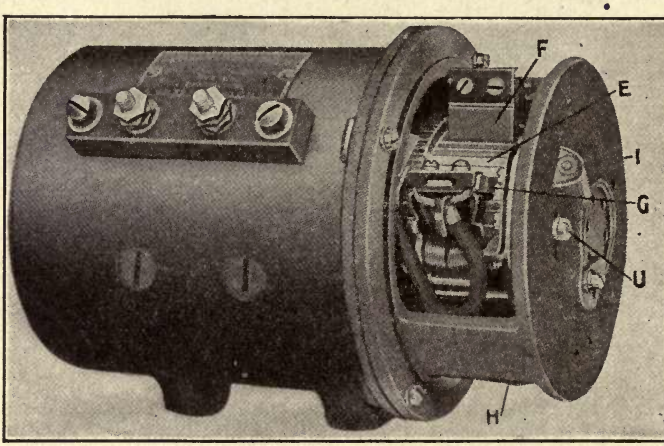


Fig. 190.—Wagner generator.

changes somewhat with the speed of rotation of the armature, due to the effect which that rotation has on the magnetic field. By having the brushes which supply the field current located in a certain position, the current to the field coils is automatically regulated in the desired manner. Ignition and starting generators of this type are made by both the Remy Electric Co. and the Wagner Electric Co. The Wagner generator has four brushes—two for the main current and two for the field current. The Remy generator has but three brushes—two for the main current, one of which is also connected to one end of the field winding, the third brush being connected to the other end.

The principle of the "third brush" system of field control is as follows: At slow and normal speeds the magnetic field flows from one pole to the other without distortion, being evenly distributed over the faces of the pole pieces. Under this condition the field receives full current.

At high speeds of rotation the magnetic field is distorted, being twisted or carried around in the direction of rotation. This results in a strong field at the leaving pole tip (the one farthest around in the direction of rotation) and a weak field at the approaching pole tip. The voltage at the brushes depends upon the position of the brushes with respect to the point of greatest density of the field. Hence, if the third brush to which is connected one end of the field winding, or the two extra brushes if there are two extra brushes for the field current, are so located in relation to the pole pieces that the voltage received is affected by the weakening field at the approaching pole tip as the speed increases, a smaller current will flow through the field winding. In this way, the tendency to increase

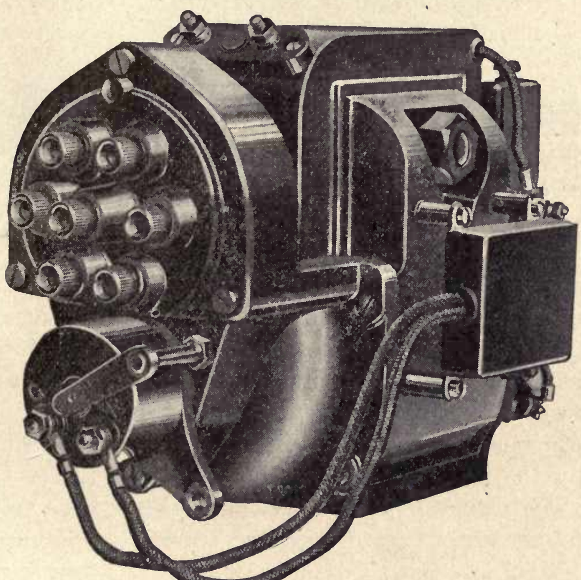


FIG. 191.—Remy ignition-generator.

the voltage as the speed increases is automatically overcome by a corresponding reduction in the strength of the field current, which reduces the strength of the magnetic field. With proper design this device may be used to give approximately a constant generator output regardless of speed, or even to give a reduced output at high speeds, if desired.

Wagner Generator.—The Wagner generator for ignition, starting, and lighting is shown in Fig. 190 with the commutator and brushes exposed to view. *E* is the commutator and *F*, *G*, *H*, and *I* are the brushes. The main brushes *H* and *I* collect the current from the armature to supply the current demands for lighting, for ignition and for charging the storage battery. The brushes *E* and *F* collect the current used for the field windings only.

Remy Generator.—The exterior of the Remy generator with third-brush control is shown in Fig. 191. In the foreground are seen the ignition distributor and circuit-breaker, which are built as a part of this generator. The generator output is regulated by the third-brush system. It is so designed as to give a large output at the moderate speeds of average city driving, in order to compensate for the frequent use of the starting motor and also to carry the ignition and lighting load at these moderate speeds. At higher speeds the output of the generator is reduced. The armature is shown in Fig. 192 with the commutator at the left. By spiraling the armature slots in which the armature coils are laid the armature is made smooth running and gives a very steady voltage.

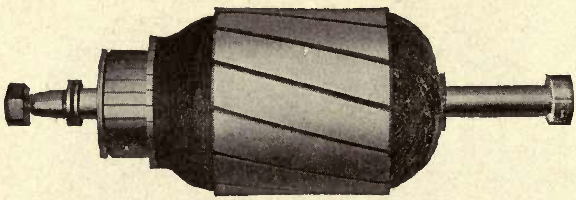


FIG. 192.—Armature of Remy generator.

97. Vibrating-regulator Field Control.—This form of regulator consists of an electromagnet which acts on a vibrating arm and places a resistance in the field circuit whenever the generator output exceeds the desired amount. By thus reducing the field current, the fields are momentarily weakened and the output reduced until the arm is released and the direct circuit again closed. Under this type are included generators made by the Remy, Gray and Davis, Ward Leonard, and other companies. The regulators may be designed to keep the voltage output of the generator constant or to keep the current output constant. To give a constant voltage, the regulator is placed in a shunt circuit so that the current through it is dependent upon the voltage at the brushes of the generator. To secure a constant current, the regulator is placed in series between the generator and the battery, so that it is operated by the current delivered. The operation of these systems is the same except that one operates when the voltage rises and the other when the current rises.

Ward Leonard Vibrating Field Control.—This controller is of the constant-current type, being operated by a series coil through which passes the current from the generator to the storage battery. As shown in Fig. 193, the controller is mounted in a single unit with the reverse current cut-out or relay. The figure shows the cut-out at the left and the controller at the right. To regulate the output of the generator at different speeds the strength of the generator fields is made dependent upon the touching of the two points E and E'. The coil F on the magnet core G carries the armature current, and if this current becomes a certain amount (usually 10 amp.) the core becomes sufficiently magnetized to

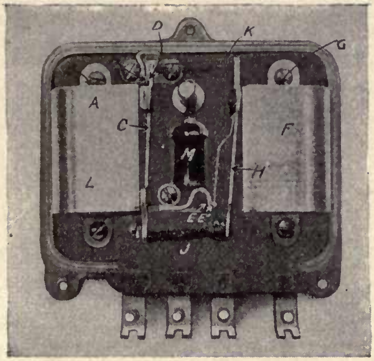


FIG. 193.—Ward Leonard-controller.

attract the finger H. This separates the contacts E and E' and forces the field current to go through the high resistance M instead of having

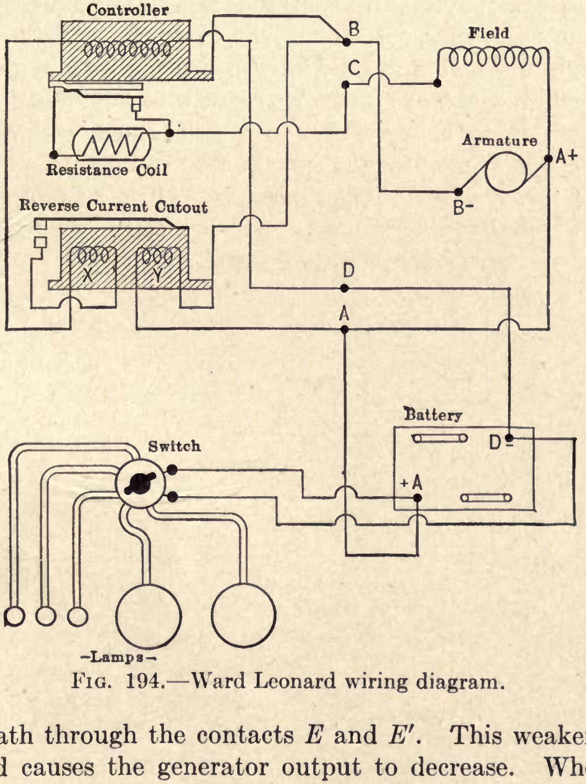


FIG. 194.—Ward Leonard wiring diagram.

the direct path through the contacts E and E'. This weakens the field strength and causes the generator output to decrease. When the current decreases to a given amount (say 9 amp.) the pull of the spring J, being now stronger than the magnetism of the core G, pulls together the points E and E'; the full field strength is restored and the current output tends to increase. Under operating conditions the finger H vibrates at such a rate as to keep the current output practically constant. The reverse current cut-out at the left in Fig. 193 connects the generator to the storage battery when the voltage is sufficient to charge the battery and opens the circuit when the generator voltage falls below that of the battery.

The wiring diagram for the generator, battery, controller, cut-out and lights is shown in Fig. 194. The positive brush $A+$ of the generator is connected directly to the positive terminal of the battery. At the point A a shunt connection is taken off and led through the shunt coil Y in the cut-out and to the point B, where it joins the main lead to the negative brush $B-$. The main lead from the negative brush leads to the reverse current cut-out points, then through the reverse series coil X (which opens the cut-out if the flow is reversed), then through the series coil of the controller, and from there to the negative terminal of the battery. The resistance coil shown just below the controller is thrown into the field circuit when the controller points are pulled open, and is cut out when the points are closed, the path of the field current then being through the points instead of through the resistance coil.

The constant-voltage vibrating regulators operate in the same manner except that the controller coil is a shunt coil so that it is affected by changes in voltage rather than by changes in current output.

Many of the firms mentioned make generators of more than one of the types which have been described, the choice depending on the conditions under which they are to be used.

CHAPTER X

MISCELLANEOUS IGNITION SYSTEMS

98. Magnetic Make-and-break Igniters.—The Allis-Chalmers Co. have for a number of years successfully used an electrically operated make-and-break igniter on their large gas engines and, although this has been abandoned for a purely mechanical igniter, it is of interest in the study of ignition devices.

Figure 195 shows this igniter, which is similar to the ordinary make-and-break igniter except for the electrical operating device at the outer end. View *A* shows a longitudinal section through the whole igniter. View *B* shows the inner end of the igniter, which is similar to any make-and-break igniter. As will be seen in view *A*, the movable electrode shaft carries at its outer end a hammer arm. In line with the movable electrode shaft, but not connected with it, is an armature shaft which carries on its inner end an L-shaped hammer shown in views *A* and *C*. This hammer is rocked magnetically at the desired instant for the spark, and the fiber face of the hammer strikes the hammer arm on the end of the igniter shaft, thus breaking the circuit at the igniter points within the cylinder. The motion of the armature shaft is produced by two electromagnets acting on a steel armature, both of which are shown in view *D*. The two coils and their pole pieces, as shown in this view, are placed on opposite sides of the armature shaft like two poles of a dynamo or motor. Between them and on the armature shaft is the steel armature, normally held in a position nearly straight across the pole faces, but inclined slightly. When the timer closes the circuit so that current passes through the coils, the poles become magnetized, and are so wound that one becomes a North pole and the other a South pole. These exert attractive forces on the ends of the armature and cause it to swing into line with the poles. This motion causes the hammer to strike the hammer arm and open the contacts within the cylinder, as before mentioned. The two coils are in series with the igniter points and act as a kick coil to give the necessary voltage for the spark.

Because of the large sizes of these engines, two of these igniters are used in each combustion chamber, thus starting combustion at two points in the gas mixture and producing complete combustion of the charge in a much shorter time. The two igniters for one combustion chamber are connected in parallel with switches between the timer and the igniters so that one can be cut out if desired.

Figure 196 shows the commutator or timer on the end of the camshaft

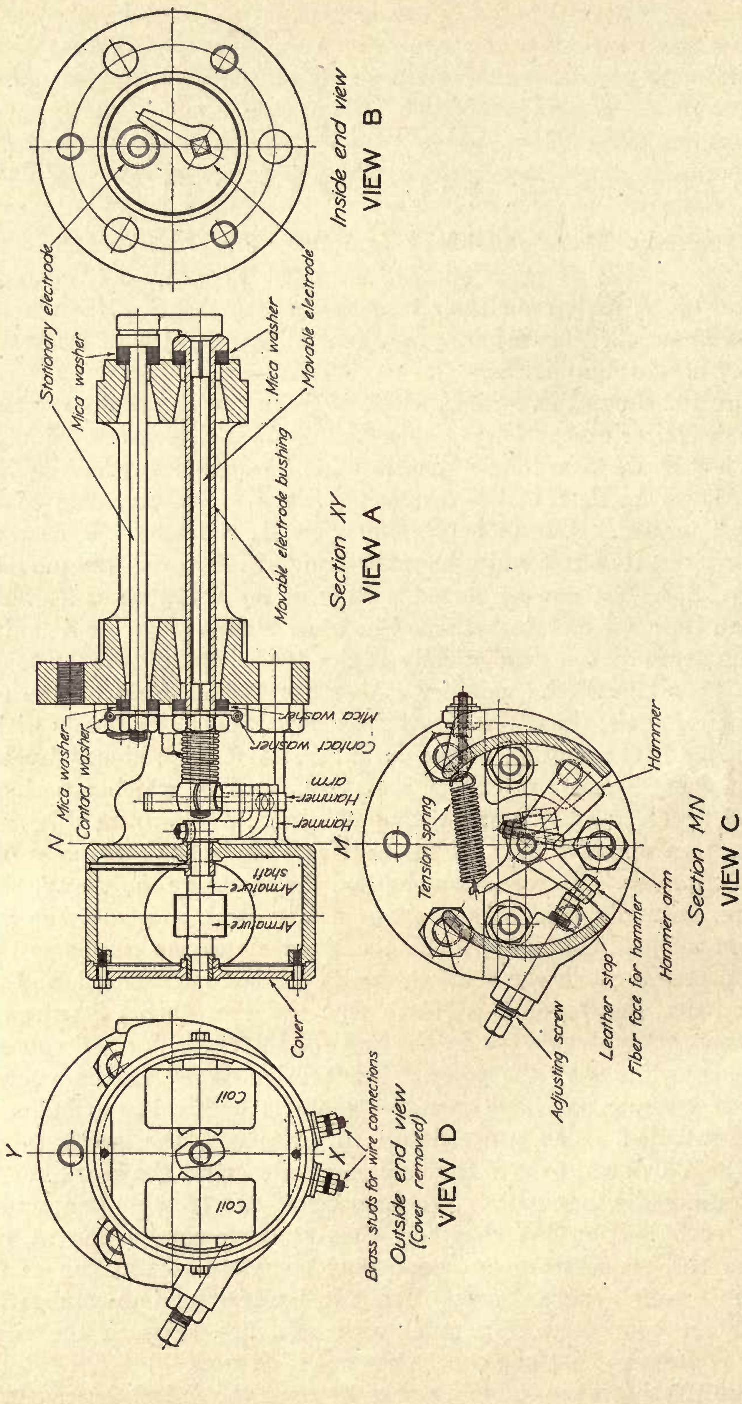


FIG. 195.—Allis-Chalmers magnetic igniter.

of the engine. The commutator consists of four copper rings with brushes riding on them. The two outside rings *A* and *D* are continuous and receive the current from a direct-current generator and supply it to the commutator. The two central rings *B* and *C* each have a short segment in connection with the adjacent outside ring, the rest of the circumference of these rings being insulated and carrying no current. When the short segments come into contact with the brushes leading to a pair of igniters they supply the current to that pair of igniters and cause them

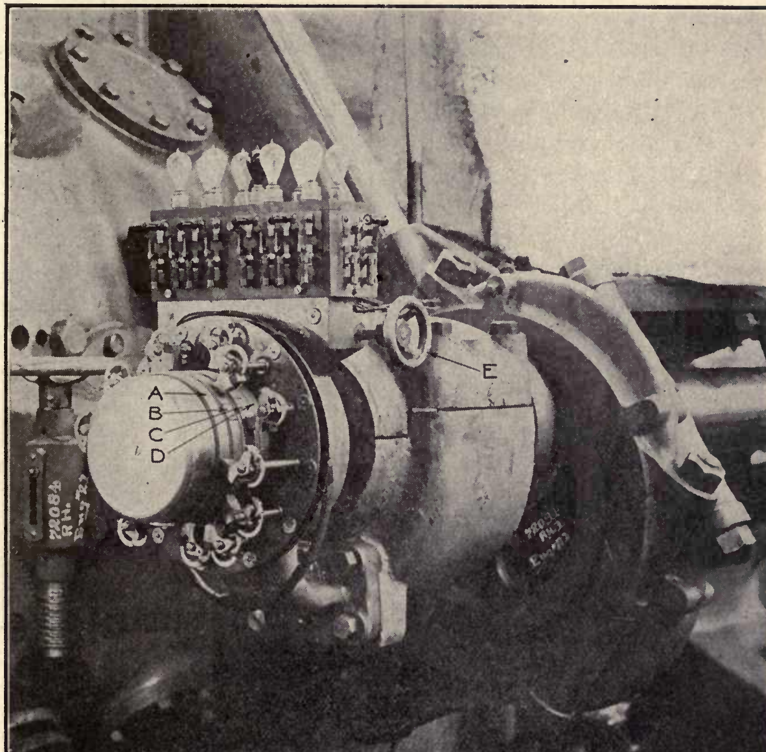
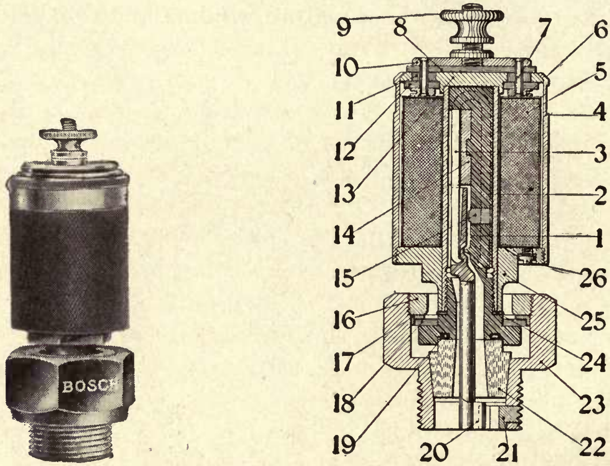


Fig. 196.—Allis-Chalmers commutator.

to operate. The brushes for the different pairs of igniters are properly spaced around the circle so that they will be operated at the proper intervals. The brush carrier can be shifted by the hand screw *E* to change the time of ignition. The lamps shown above the commutator are connected to the different igniter circuits and flash when the igniters are operated. The central lamp is on the main current supply lines.

99. Bosch Magnetic Plug Ignition.—The Bosch magnetic plug illustrated in Fig. 197 is another form of magnetically operated make-and-break igniter. It is used in connection with a specially constructed Bosch low-tension alternating-current magneto. The magneto current is brought to the terminal nut 9 on the top of the plug, whence it passes through the coil winding 5. The lower end of the coil is electrically connected by the screw 26 to the body of the coil, which is insulated from the plug body 23 by a steatite cone 22 and the mica washers 18. From the coil body the current passes into the interrupter lever 20, which is normally held in contact with the fixed contact piece 21 on the plug body by the U-shaped spring 3. The interrupter lever 20 extends upward into the center of the coil, its upper end being indicated at 1. It is mounted on a knife edge, with the U-shaped spring 3 pressing on it



1. Interrupter lever.
2. Pole piece.
3. U-shaped spring.
4. Iron sleeve.
5. Magnetic coil.
6. Current conducting ring.
7. Current conducting rivet.
8. Mica washer.
9. Nut for terminal.
10. Current-carrying plate.
11. Insulating bush.
12. Mica ring.
13. Upper magnet yoke piece.
14. Detachable brass piece.
15. Separating brass piece.
16. Internal ring nut.
17. Center ring.
18. Mica plates.
19. Packing washer.
20. Contact piece on interrupter.
21. Contact piece on plug body.
22. Steatite cone.
23. Hexagon head with thread of plug.
24. Packing ring for coil.
25. Lower magnet yoke piece.
26. Connection screw for winding.

Fig. 197.—Bosch magnetic plug.

just below this knife edge so as to hold its lower end 20 in contact with the fixed contact piece 21 on the plug body. Within the coil is the pole piece or core 2 which becomes magnetized whenever current passes through the coil winding. If the magnetizing action is sufficiently strong it will overcome the spring and attract the upper end of the interrupter lever, thus breaking the circuit at the contact points 20 and 21. A small brass separating piece 15 prevents the interrupter lever from coming into contact with and sticking to the pole piece. A weak current may be passed through the plug without the action being sufficient to break the circuit at the igniter points. A sudden impulse of current from the magneto, however, will break the circuit and with the inductive action of the magneto armature and the coil on the igniter will produce a powerful discharge at the gap.

The magnetos for use with this igniter may take different forms. In one form a simple low-tension oscillator is used. The current wave generated by the tripping of the oscillator armature is shot through the magnetic plug and produces a spark at the igniter points in the manner just described. With a revolving armature magneto a circuit-breaker is used in the magneto circuit. In one form the armature carries a single low-tension winding. When the circuit-breaker is closed, the armature current takes this short-circuit path and only a feeble current passes through the igniter, which is connected in parallel with the circuit-breaker. When the circuit-breaker points are opened, the usual inductive action occurs in the armature winding and this induced current, having no other path, discharges through the magnetic plug and produces the spark at the igniter points. In another form of rotating armature magneto only a part of the armature winding is short-circuited at the circuit-breaker, the current generated in the main winding passing through the plug. This current is not, however, sufficiently powerful to operate the plug until the instant that the circuit-breaker opens, when the induced current thus produced reinforces the current in the main winding and causes the action of the plug as before described.

These magnetic plugs may be used on multi-cylinder engines, the current being supplied by a single magneto with a distributor. On large cylinders two or more plugs may be used to start combustion at different points in the combustion chamber simultaneously, the plugs being connected in parallel. The plugs are easily disassembled for cleaning, when necessary, usually about once in 8 days. The magnetic plug offers a complete ignition system without any mechanical connections other than the drive for the magneto, as the interruption of the current is caused by the magneto current itself. Being entirely a low-tension system, it presents no insulation difficulties. The ignition timing is effected by moving the circuit-breaker housing on the magneto.

100. High-tension Oscillators.—The Bosch Magneto Co. has developed a high-tension oscillator in which the armature is rocked from position and then quickly drawn back by springs as in the oscillators already described, but with the difference that it is used with an ordinary spark plug in the cylinder, a high-tension current being produced in the armature winding. To accomplish this the armature carries the customary low-tension and high-tension windings of the ordinary high-tension magneto. The primary winding is provided with an interrupter and condenser, the interrupter parts being mounted on a disc moving with the armature, while the cam is stationary. As the armature is rocked from its normal position the interrupter points close and short-circuit the primary winding. When the armature reaches the position of maximum current on its recoil the interrupter lever strikes the cam and the primary circuit is interrupted, thus inducing a high-tension current in the secondary winding. One end of the secondary winding is grounded. The other end makes connection through a brush to the single high-tension wire leading from the magneto to the insulated terminal of the plug. As no distributor can be provided, this magneto will serve only for a single cylinder. The provision for timing must be made on the tripping mechanism. This magneto is made in two types, wound for compressions of not to exceed 8 and 12 atmospheres (118 and 176 lb.).

101. Two-point Ignition Systems.—The combustion of the explosive charge in an engine cylinder is not an instantaneous affair, but requires an appreciable interval of time depending upon the size of the combustion chamber, the quality of the mixture, and the nature of the fuel.

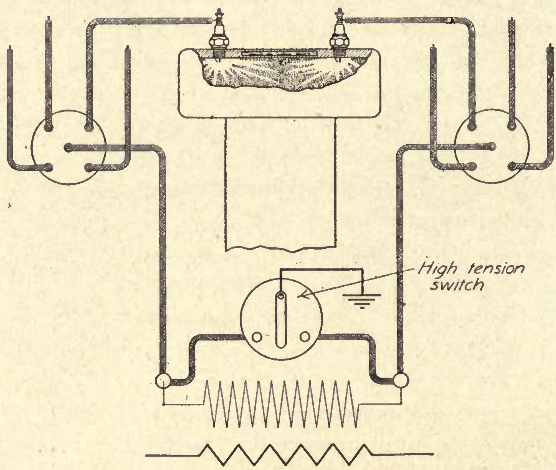


Fig. 198.—Double-distributor two-point ignition system.

The securing of the maximum amount of work from the fuel requires that this combustion be secured in the shortest possible time at the end of the compression stroke and the beginning of the expansion stroke. The time of combustion can be reduced by causing ignition simultaneously at different points in the combustion chamber. Mention of this has already been made in Arts. 98 and 99. The use of two-point ignition has not been common in automobile practice because of the small sizes of the cylinders, but some use of it has been made for racing purposes, where quick combustion is especially desirable because of the high speeds of the engines, and for T-head engines, where the charge is spread out in a long shallow combustion chamber. The arrangement of a Remy magneto with two distributors at the two ends of the secondary winding has already been illustrated in Fig. 131, Chap. VII. The principle of this system is better illustrated in Fig. 198, which shows the two ends of the secondary winding of the coil connected to the central posts of two distributors, each serving a plug in each cylinder. In order to complete its circuit, the secondary or high-tension current must leap the gaps at both plugs, passing through both distributors and plugs. The only grounded part of the circuit is that between the two plugs. Either set of plugs may be cut out of service by the switch. The switch may be used to connect either end of the secondary winding of the coil to the ground, thus rendering the distributor and plugs on that side of the secondary circuit inoperative, since the current from the ungrounded end of the coil has then a direct return path through the ground to the other end of the coil after leaping the gap at the one plug.

A magneto with a single distributor may be made to produce double ignition by the use of a double plug in connection with an ordinary plug, as shown in Fig. 199. The double plug has two insulated electrodes, insulated from each other and also from the metal of the engine. The current is brought to the one insulated electrode, jumps the gap to the

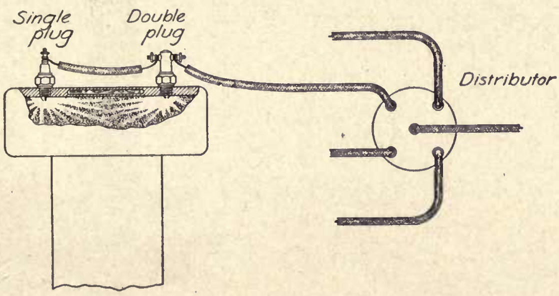


Fig. 199.—Series-plug ignition system.

other insulated electrode, from which it is led to the insulated electrode of the other plug. Here it leaps this gap and returns to the coil through the ground. This is sometimes called "Series Plug Ignition."

102. Eight- and Twelve-cylinder Ignition Systems.—The Cadillac eight-cylinder engine secures its ignition from a Delco battery-distributor system, using a single transformer coil with an eight-point distributor and a single interrupter having eight points and notches on the cam, as shown in Fig. 200.

A magneto for use on an eight-cylinder engine would have to produce four sparks per revolution of the engine. For a shuttle-wound armature, giving two sparks per revolution, this would mean an armature speed of twice that of the crankshaft. Some of the inductor types of magnetos (K.-W. and Pittsfield) will produce four sparks per revolution of the armature and can thus be driven at crankshaft speed.

The Packard "twin-six" engine uses two complete six-cylinder ignition systems of the battery-distributor type. There are two separate igniter heads each having a primary interrupter and a distributor for six cylinders. The two igniters are mounted on the opposite ends of a short horizontal shaft driven by spiral gearing at its center. The igniter cams are mounted at an angle of 30° corresponding to one-half the crank angle between the explosions. The igniter housings are operated simultaneously by the spark-control lever. There are separate coils for the two sets of cylinders.

The Dixie magneto has been developed in a special form for twelve-cylinder ignition purposes. This magneto is specially constructed so as to produce four sparks per revolution of its rotor, and it must be driven at one and one-half times crankshaft speed for a twelve-cylinder engine. To produce four sparks per revolution, the rotor has been provided with four poles, two North and two South, thus changing the direc-

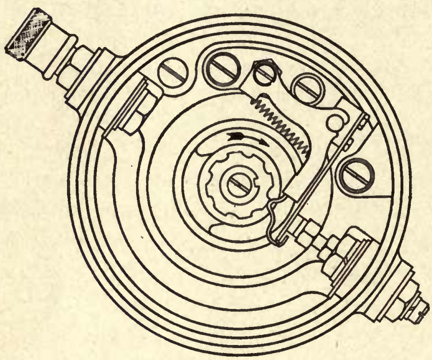


FIG. 200.—Delco interrupter for eight-cylinder Cadillac engine.

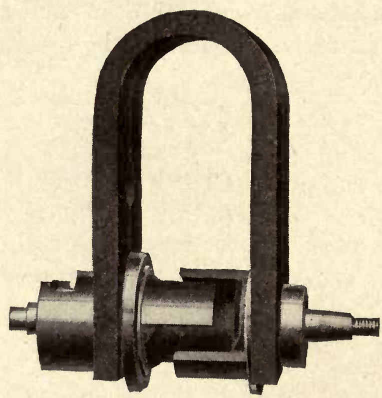


FIG. 201.—Magnets and rotor of Dixie 12-cylinder magneto.

tion of the flux through the coil four times per revolution. The magnets with the rotor are shown in Fig. 201.

As there are four sparks per revolution of the armature there must be a four-point cam for the interrupter, as may be seen in Fig. 202, which shows the magneto with interrupter cap and distributor cap removed. In order to distribute the sparks to twelve cylinders and yet maintain a safe distance between the distributor segments, a novel distributor construction has been used, as illustrated in Fig. 203. This consists of a pair of six-cylinder distributors placed side by side, but moulded together and having a double finger or rotating member, with the contacts so arranged that one segment in each row is alternately in contact. The high-tension current is collected from the secondary coil winding by the brush C, which is in contact with the secondary winding, and is conducted through the center of the rotating member to the brush D, and thence to the spoke-shaped sector S in the distributor cover. From this sector the current is given alternately to the two brushes A_1 and B_1, these brushes lacking 30° of being directly opposite each other. Thus a connection is made to a plug every 30° in the rotation of the distributor or every 60° in the rotation of the crankshaft. The brush B_1 connects with the brush B_2, while brush A_1 connects with brush A_2. B_2 distributes

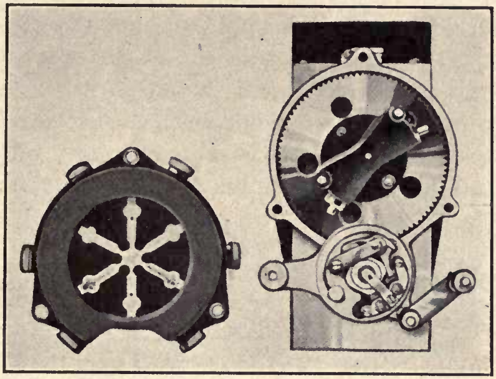
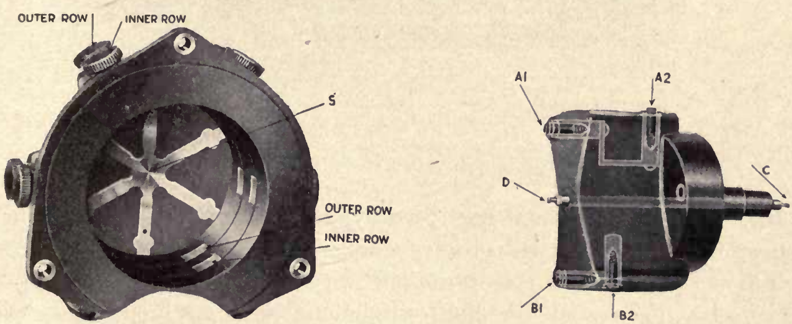


FIG. 202.—Dixie 12-cylinder magneto distributor cap removed.

the current to the outer row of segments and A_2 to the inner row of segments. By this construction the segments are no nearer than in a six-cylinder distributor and there is no danger of the spark jumping to the wrong segment, as the connections are alternately made at opposite extremities of the distributor arm.

As in the other Dixie magnetos, the pole pieces and coils are moved



Distributor cap. Distributor arm.

FIG. 203.—Dixie 12-cylinder distributor.

with the interrupter housing to change the time of spark, thus making the spark of the same intensity at all positions of the interrupter (see Fig. 163).

103. High-tension Magnetos for Single-cylinder Engines.—For single-cylinder motorcycles it is customary to use either a battery ignition system or a high-tension magneto. Figure 204 shows a section of the

National magneto for this purpose. As only one plug is to be supplied with current, a slip ring and brush are used to collect the current from the armature coil and lead it directly to the plug. The interrupter has a single-point cam. As a single spark is wanted for two revolutions of the armature the magneto may be driven at one-half crankshaft speed. If, however, this is found to be too slow for satisfactory ignition the magneto may be driven at crankshaft speed. This will produce two sparks per cycle of the engine, but as the second spark takes place near the end of the exhaust stroke it will do no harm. If the spark is retarded much beyond dead center, however, the second spark will occur early on the suction stroke and may cause backfiring through the carburetor. This can be stopped by advancing the spark.

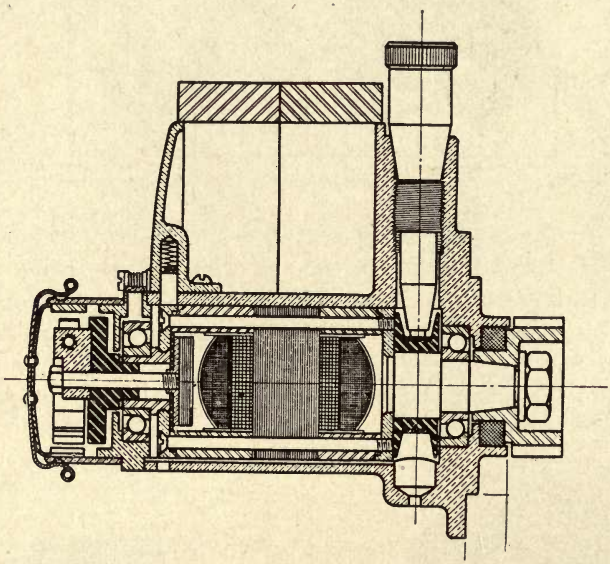


FIG. 204.—National magneto for single-cylinder motorcycle.

104. Magneto Ignition for Two-cylinder Engines.—In the high-tension magneto for two-cylinder engines with equal times between explosions, the magneto is provided with a two-point cam and the armature is driven at one-half crankshaft speed. The high-tension current is directed alternately to the two spark plugs by having two brushes on opposite sides of the collector ring, the metal segment of the ring having a length of 180° or less. Figure 205 shows the interrupter and collector ends of the Bosch DU2 magneto. As this is a shuttle-wound high-tension magneto, the interrupter parts are carried on a disc with the armature and the cam blocks are on the inside of the interrupter housing.

Another form of magneto ignition is seen in Fig. 206, where a single cam is used on the magneto interrupter and the armature is driven at crankshaft speed. The two ends of the secondary coil are connected to the two plugs, thus placing them in series and causing sparks in the two cylinders simultaneously at intervals of 360° of crankshaft rotation.

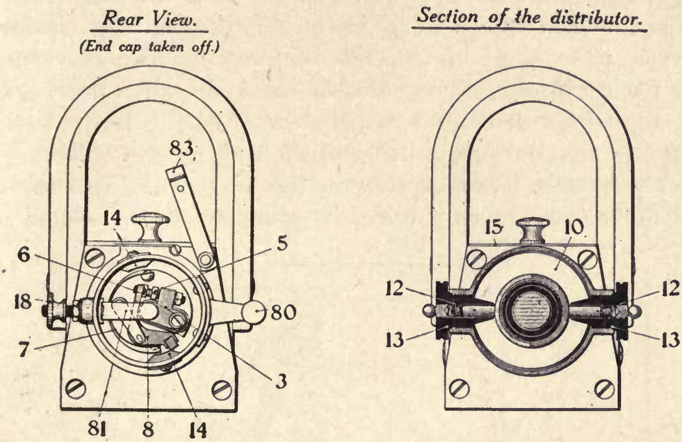


FIG. 205.—Bosch DU2 magneto.

As one piston will be at the end of its exhaust stroke when the other is at the end of its compression stroke, the extra spark in the one cylinder will do no harm unless the spark is retarded too far past dead center. This might bring the spark in the one cylinder during the early part of

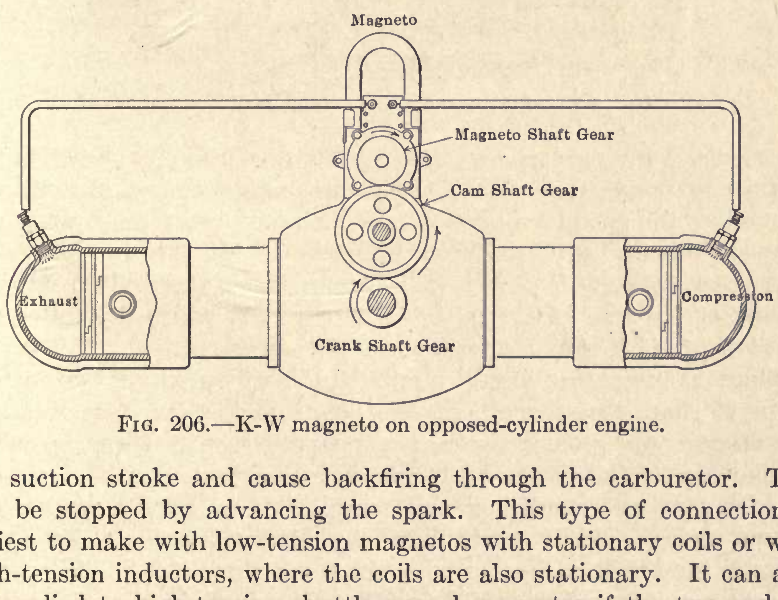


FIG. 206.—K-W magneto on opposed-cylinder engine.

the suction stroke and cause backfiring through the carburetor. This can be stopped by advancing the spark. This type of connection is easiest to make with low-tension magnetos with stationary coils or with high-tension inductors, where the coils are also stationary. It can also be applied to high-tension shuttle-wound magnetos if the two ends of the secondary winding are insulated and two separate collecting brushes are used. The figure shows the K.-W. high-tension inductor magneto, which has stationary coils.

105. Magneto Ignition for Twin-cylinder V Motors.—The V motor used on twin-cylinder motorcycles does not have the explosions equally spaced, as the two pistons work on the same crank. As shown in Fig. 207, if there is an angle of 45° between the cylinders, the explosion in cylinder I will be followed by 405° of crank motion before cylinder II will fire, and then there will be an interval of 315° before cylinder I will fire again, the crank rotation being to the right or clockwise.

This necessitates a special construction of the magneto to take care of these unequal intervals. With the ordinary shuttle-wound magneto

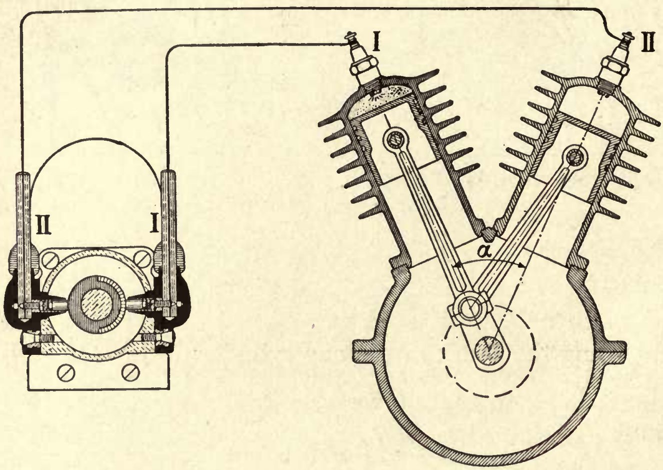


Fig. 207.—Arrangement of twin-cylinder V-motor.

the armature will produce two sparks in its revolution, so the armature is driven at one-half crankshaft speed (assuming a four-stroke engine). To produce the unequal intervals the interrupter cam points are spaced unequally about the circle. For cylinders at 45° the cam points or blocks are set at 202½° and 157½° from each other. This unequal spacing of the cam blocks is shown in Fig. 208 which illustrates the Splitdorf type EV magneto for V cylinder engines.

Since an alternating-current magneto ordinarily produces two current waves of short duration at opposite points in the armature rotation, it is necessary to prolong these current waves or space them unequally to take care of the unequal intervals between sparks and also to provide for some spark advance and retard without getting outside the current waves. This is accomplished by altering the shape of the pole pieces or the armature tips, or both. A spark range of 20° to 25° on the armature, corresponding to 40° to 50° on the crankshaft, can be provided. The interrupter cam blocks are usually marked for cylinders I and II, as are also the secondary terminals. The rear cylinder is usually called cylinder I. The common angles between cylinders are 42°, 45°, and 50°. The magnetos are built differently for the different angles and it is necessary to specify the angle in ordering a magneto or its parts.

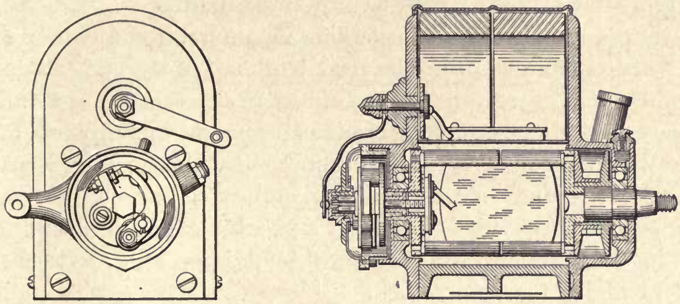


FIG. 208.—Splitdorf EV magneto.

106. Ignition Timing.—Correct ignition timing is one of the most important points in engine economy. The best efficiency will be obtained when the time of ignition is so regulated that the greater part of the combustion occurs while the crank is passing the inner or upper dead center. If any great part of the combustion occurs before the dead center is reached, there will be an undue pressure exerted against the further motion of the piston in completing the compression. If the combustion is delayed, the full fuel energy is not available for the whole expansion stroke and there is a consequent loss in the amount of work secured from the fuel.

The rate at which the flame spreads through the fuel mixture depends on the fuel and on the mixture. A weak mixture will burn more slowly than a well-balanced one. Likewise, an over-rich mixture will burn more slowly. A fuel low in heating value will also burn more slowly than one high in heat units. Fundamentally, the rate of flame propagation through the charge is a question of the intensity of the heat generated by the combustion. The spark starts combustion in a small sphere surrounding the igniter points. The heat thus generated is transmitted to the surrounding charge, which in turn burns and passes the combustion on to the next layers. The rate of propagation thus depends on the intensity of the heat generated in each unit of volume of the mixture. Weak gases or mixtures, therefore, mean slower combustion. The value of high compressions is also apparent. If the charge is compressed into a smaller space the intensity of the heat generated in each unit of space is greater; the flame also has a shorter distance to travel to ignite the whole charge. Those fuels which give mixtures high in heating value, such as gasoline and kerosene, produce quicker combustion than weak fuels such as blast-furnace gas or producer gas.

The location of the igniter is also important in this respect. If near the center of the combustion chamber, the combustion will spread through the whole mass more quickly than if ignition occurs at one corner of the combustion chamber. To lessen the time for securing combustion, large engines are provided with two or three igniters.

The thermal efficiency of an engine depends on the extent to which the gases are expanded after the heat is liberated by combustion. Delayed combustion, therefore, means a loss in efficiency. Ignition occurring after expansion has begun is also slower, as the expansion reduces the flame temperature. As the volume of the charge is increasing, this also means a greater time to reach all points in the charge. Furthermore, since the gases are exposed to a greater expanse of cylinder wall the heat losses to the cooling water will be greater, thus further reducing the heat available for doing work.

The timing of ignition to secure the best results depends on too many quantities to permit of any general statements or rules. The speed of the engine, size of combustion chamber, location of igniter, kind of fuel, quality of mixture, as well as the mechanical and electrical lag in the ignition apparatus, are all factors which must be considered in determining the best setting for the ignition. The best way is to use an indicator or manograph to show the pressure changes in the cylinder. Lacking this, it is generally believed that the best results are obtained with the ignition advanced as far as possible without causing the engine to pound.

Nearly every ignition system is provided with means of varying the time of ignition. For many stationary engines but two ignition settings are provided—one for starting, where the ignition is set at or a little after dead center, and one for the running speed. A few engines, both stationary and automobile, have fixed ignition. These are small engines which can be turned by hand fast enough to pass the spark without kicking back. Such a fixed timing is apt to be too late to secure the best results at high speeds, but the results obtained are frequently better than where the timing is left entirely to the judgment of the operator. For automobile use the automatic spark advance mechanism will produce better results than where the timing is left to the average operator. These mechanisms advance the timing as the speed increases. While the time required for combustion is independent of the speed, the angle on the timer shaft necessary to give this time is greater with higher speeds.

On automobile engines, the spark should be shifted to a later position on a heavy pull or a grade. This is necessary because of the slower speed of the engine and also because with open throttle the fuller charge will give quicker combustion. The ordinary advance before dead center for running speeds will vary from 20° to 40° before center. On racing cars an advance of as much as 90° is sometimes used.

For stationary engines the ordinary advance will vary from 8° or 10° on slow-speed engines to 40° on very small high-speed engines. The necessity for advance on small high-speed engines, due to the greater rotative speed, is greater than that due to the larger volume of mixture in large engines. As has been mentioned before, when an oscillating magneto is installed on an engine in place of a direct-operated make-

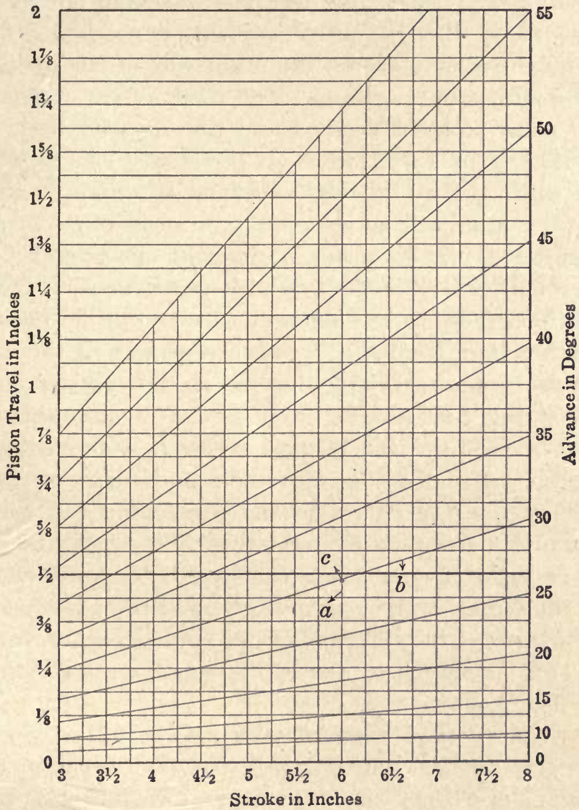


FIG. 209.—Chart giving relation between piston travel and crank angle from inner dead center for a connecting rod ratio of 4½.

and-break igniter, it is necessary to advance the time of tripping the ignition about 15° because of the time that elapses between the instant of tripping and the actual production of the spark, which occurs after the armature has returned to its normal position.

On engines using producer gas or blast-furnace gas it is desirable to have a ready means of changing the spark while the engine is running, as changes in the quality of the gas or in the governor position will require shifting the spark to secure satisfactory operation.

It is frequently desirable to locate accurately the dead center of an engine. This is difficult to do by the eye if the crank and connecting rod are visible and is even harder to do by measuring the piston movement, as that motion is so small near the dead center. The only accurate method is what is commonly called "tramming," because of the use of a trammel or some other fixed reference point near the flywheel rim. With the crank some 30 or more degrees to one side of the center, so that the piston has a considerable motion for a few degrees of crank motion, a point is marked on the flywheel rim from our fixed reference point. At the same time the piston position is marked. The wheel is then turned until the crank is on the other side of the dead center and the piston is in the same position. The point of the flywheel opposite the reference point is again marked and the distance between the two points thus marked on the flywheel is bisected. The flywheel is then turned back until the point thus obtained is opposite the reference point, when the engine will be set exactly on dead center. Any desired number of degrees of crank motion may now be obtained by marking off one three-hundred-sixtieth of the flywheel circumference for each degree.

It is sometimes more convenient to locate certain positions by piston movement rather than from the flywheel, especially if the crank case is enclosed and there is an available opening in the cylinder head through which a measuring rod can be inserted. The accompanying chart, Fig. 209, may be used for this purpose where it is desired to secure the relation between inches of piston movement and angles of crank motion. For any given stroke the length of the connecting rod will affect the piston position for a given crank angle, this chart having been calculated for an average ratio of connecting rod length to crank radius of $4\frac{1}{2}$. In the chart the stroke of the engine is given at the bottom, the inclined lines and the figures at the right indicating the degrees of rotation of the crank shaft, and the figures at the left giving the corresponding piston motion from dead center.

For a given stroke and angle of advance, we follow vertically from the stroke as given at the bottom until we come to the inclined line of the required angle. From this intersection we follow horizontally to the left to find the corresponding piston motion in inches.

For a given piston motion and stroke, from the piston motion at the left we follow horizontally to the right until we come to the vertical line representing the stroke. The position of this point of intersection with reference to the inclined lines will indicate the corresponding crank angle.

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